No. 2023-1715

IN THE

United States Court of Appeals

FOR THE FEDERAL CIRCUIT

JIAXING SUPER LIGHTING ELECTRIC APPLIANCE, CO., LTD., OBERT, INC.,
Plaintiffs-Appellees,

v.

CH LIGHTING TECHNOLOGY CO., LTD., ELLIOTT ELECTRIC SUPPLY, INC.,
SHAOXING RUISING LIGHTING CO., LTD.,
Defendants-Appellants.

On Appeal from the United States District Court
for the Western District of Texas
No. 6:20-cv-00018, Hon. Alan D. Albright

OPENING BRIEF FOR DEFENDANTS-APPELLANTS CH LIGHTING TECHNOLOGY CO., LTD., ELLIOTT ELECTRIC SUPPLY, INC., AND SHAOXING RUISING LIGHTING CO., LTD.

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REPRESENTATIVE PATENT CLAIMS AT ISSUE ON APPEAL

U.S. Patent No. 10,295,125, Claim 1:

An LED tube lamp, comprising:

[a] a lamp tube;

two end caps, each of the two end caps coupled to a respective end of the lamp tube;

a power supply disposed in one or two end caps;

[b] an LED light strip disposed on an inner circumferential surface of the lamp tube, the LED light strip comprising a mounting region and a connecting region, the mounting region for mounting a plurality of LED light sources, the connecting region having at least two soldering pads, and the mounting region and the connecting region being electrically connected to the plurality of LED light sources and the power supply; and

[c] a protective layer disposed on a surface of the LED light strip, the protective layer having a plurality of first openings to accommodate the plurality of LED light sources and at least two second openings to accommodate the at least two soldering pads.

U.S. Patent No. 10,352,540, Claim 13:

An LED tube lamp, comprising:

[a] a tube, comprising:

a main body; and

two rear end regions respectively at two ends of the main body;

[b] two end caps respectively sleeving the two rear end regions, each of the end caps comprising:

a lateral wall substantially coaxial with the tube, the lateral wall sleeving the respective rear end region;

an end wall substantially perpendicular to the axial direction of the tube; and

two pins on the end wall for receiving an external driving signal;

[c] an LED light strip disposed on an inner circumferential surface of the main body with a plurality of LED light sources mounted thereon;

[d] a power supply comprising a circuit board and configured to drive the plurality of LED light sources, the circuit board disposed inside one of the rear end regions and one of the end caps;

[e] an adhesive disposed between each of the lateral wall and each of the rear end regions; and

[f] a diffusion film disposed on the glass lamp tube so that light emitted from the LED light sources passing through the inner surface of the glass lamp tube and then passing through the diffusion film on the glass lamp tube.

U.S. Patent No. 10,352,540, Claim 14:

The LED tube lamp of claim 13, wherein a portion of the circuit board, one of the rear end regions, the adhesive and one of the lateral wall are stacked sequentially in a radial direction of the LED tube lamp.

U.S. Patent No. 9,939,140, Claim 1:

An installation detection circuit configured in a light-emitting diode (LED) tube lamp configured to receive an external driving signal, the installation detection circuit comprising:

a pulse generating circuit configured to output one or more pulse signals; wherein the installation detection circuit is configured to detect during at least one of the one or more pulse signals whether the LED tube lamp is properly installed on a lamp socket, based on detecting a signal generated from the external driving signal; and

a switch circuit coupled to the pulse generating circuit, wherein the one or more pulse signals control turning on and off of the switch circuit;

wherein the installation detection circuit is further configured to:

when it is detected during one of the one or more pulse signals that the LED tube lamp is not properly installed on the lamp socket, control the switch circuit to remain in an off state to cause a power loop of the LED tube lamp to be open; and

when it is detected during one of the one or more pulse signals that the LED tube lamp is properly installed on the lamp socket, control the switch circuit to remain in a conducting state to cause the power loop of the LED tube lamp to maintain a conducting state,

wherein the signal generated from the external driving signal is a sampling signal on the power loop, the installation detection circuit further comprises a detection determining circuit configured to detect the sampling signal for determining whether the LED tube lamp is properly installed on the lamp socket, and the power loop includes the switch circuit and the detection determining circuit, and

wherein the pulse generating circuit is configured to output one or more pulse signals independent of whether the detection determining circuit detects the sampling signal.

UNITED STATES COURT OF APPEALS
FOR THE FEDERAL CIRCUIT

CERTIFICATE OF INTEREST

Case Number 2023-1715

Short Case Caption Jiaxing Super Lighting Electric Appliance, Co., Ltd. v. CH Lighting Technology Co., Ltd.

Filing Party/Entity CH Lighting Technology Co., Ltd., Elliott Electric Supply, Inc., Shaoxing Ruising Lighting Co., Ltd.

Instructions:

1. Complete each section of the form and select none or N/A if appropriate.
2. Please enter only one item per box; attach additional pages as needed, and check the box to indicate such pages are attached.
3. In answering Sections 2 and 3, be specific as to which represented entities the answers apply; lack of specificity may result in non-compliance.
4. Please do not duplicate entries within Section 5.
5. Counsel must file an amended Certificate of Interest within seven days after any information on this form changes. Fed. Cir. R. 47.4(c).

I certify the following information and any attached sheets are accurate and complete to the best of my knowledge.

Date: 07/25/2023

Signature: /s/ Jeffrey A. Lamken

Name: Jeffrey A. Lamken

1. Represented Entities. Fed. Cir. R. 47.4(a)(1).	**2. Real Party in Interest.** Fed. Cir. R. 47.4(a)(2).	**3. Parent Corporations and Stockholders.** Fed. Cir. R. 47.4(a)(3).
Provide the full names of all entities represented by undersigned counsel in this case.	Provide the full names of all real parties in interest for the entities. Do not list the real parties if they are the same as the entities. ☑ None/Not Applicable	Provide the full names of all parent corporations for the entities and all publicly held companies that own 10% or more stock in the entities. ☐ None/Not Applicable
CH Lighting Technology Co., Ltd.		None/Not Applicable
Elliott Electric Supply, Inc.		None/Not Applicable
Shaoxing Ruising Lighting Co., Ltd.		CH Lighting Technology Co., Ltd.

☐ Additional pages attached

4. Legal Representatives. List all law firms, partners, and associates that (a) appeared for the entities in the originating court or agency or (b) are expected to appear in this court for the entities. Do not include those who have already entered an appearance in this court. Fed. Cir. R. 47.4(a)(4).

☐ None/Not Applicable ☑ Additional pages attached

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5. Related Cases. Other than the originating case(s) for this case, are there related or prior cases that meet the criteria under Fed. Cir. R. 47.5(a)?

☑ Yes (file separate notice; see below) ☐ No ☐ N/A (amicus/movant)

If yes, concurrently file a separate Notice of Related Case Information that complies with Fed. Cir. R. 47.5(b). **Please do not duplicate information.** This separate Notice must only be filed with the first Certificate of Interest or, subsequently, if information changes during the pendency of the appeal. Fed. Cir. R. 47.5(b).

6. Organizational Victims and Bankruptcy Cases. Provide any information required under Fed. R. App. P. 26.1(b) (organizational victims in criminal cases) and 26.1(c) (bankruptcy case debtors and trustees). Fed. Cir. R. 47.4(a)(6).

☑ None/Not Applicable ☐ Additional pages attached

CERTIFICATE OF INTEREST – ADDENDUM

4. Legal Representatives. List all law firms, partners, and associates that (a) appeared for the entities in the originating court or agency or (b) are expected to appear in this court for the entities. Do not include those who have already entered an appearance in this court. Fed. Cir. R. 47.4(a)(4).

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STATEMENT OF RELATED CASES

No appeal has previously been taken from the proceedings below. The Court's decision in this appeal may directly affect or be directly affected by the following pending proceedings involving the patents asserted here:

- Reexamination of U.S. Patent No. 10,295,125, Control No. 90/015,003 (USPTO Examination Art Unit 3992);
- Reexamination of U.S. Patent No. 10,352,540, Control No. 90/015,002 (USPTO Examination Art Unit 3992);
- *Current Lighting Solutions, LLC v. Jiaxing Super Lighting Electric Appliance Co., Ltd.*, Case No. IPR2023-00271 (Patent Trial and Appeal Board) (U.S. Patent No. 10,295,125);
- *Current Lighting Solutions, LLC v. Jiaxing Super Lighting Electric Appliance Co., Ltd.*, Case No. IPR2023-00676 (Patent Trial and Appeal Board) (U.S. Patent No. 9,939,140);
- *Jiaxing Super Lighting Electric Appliance Co., Ltd. v. Current Lighting Solutions, LLC d/b/a GE Current*, No. 6:22-cv-00534-ADA-DTG (W.D. Tex.) (U.S. Patent Nos. 10,295,125 and 9,939,140).

INTRODUCTION

LED tube lamps have been around for years. Here, plaintiffs asserted patents claiming two supposed advances over the prior art: (1) attaching the LED strip, or attaching light-diffusion film, directly to a lamp's tube, and (2) a shock-protection system that allegedly reversed the order of operations from existing technologies. In each instance, preexisting products and references employed those technologies or rendered them obvious.

At trial, however, the district court granted plaintiffs partial judgment as a matter of law on invalidity. It ruled there was insufficient evidence that the prior-art products were available before the patents' priority date. That ruling rested on the mistaken conclusion that expert testimony cannot constitute substantial evidence unless the facts and data on which the expert relied are themselves admitted as evidence "'in the record' at trial." Appx66. Rule 703 says the opposite: The facts and data underlying an expert's opinions "need ***not*** be ***admissible***," much less ***admitted***. Fed. R. Evid. 703 (emphasis added). Compounding the error, the court erroneously excluded other invalidity evidence—the materials defendants' expert considered and a document showing that one plaintiff possessed invalidating products before the priority date.

Plaintiffs, moreover, were allowed to turn their claims into the proverbial "nose of wax." When contesting invalidity, they distinguished a prior-art system because it detected proper installation by measuring impedance (rather than pulses of voltage, as plaintiffs urged the claims require). But when arguing infringement, plaintiffs reversed course, accusing products that detect proper installation by measuring impedance.

On damages, plaintiffs failed to adjust the royalty rates from plaintiffs' portfolio licenses—covering 260+ patents—to account for the three patents-in-suit. Plaintiffs' expert proposed, and the jury adopted, a ***higher*** royalty for ***any one*** of the asserted patents than plaintiffs ever received for the ***entire portfolio***. That methodology was unreliable and cannot support the damages award.

JURISDICTIONAL STATEMENT

The district court had jurisdiction under 28 U.S.C. §§1331, 1338(a). It entered judgment on the jury's verdict on July 29, 2022. Appx1-3. Defendants filed timely Rule 50(b) and Rule 59 motions on August 26, 2022. Appx363 (Dkts. 291, 292). The district court denied those motions on March 8, 2023, Appx46-94, and entered a revised final judgment disposing of all claims on March 17, 2023, Appx95-99. Defendants timely appealed on March 27, 2023. Appx22128-22310. This Court has jurisdiction under 28 U.S.C. §1295(a)(1).

STATEMENT OF THE ISSUES

1. Whether the district court erred in excluding evidence on invalidity and granting partial JMOL for plaintiffs on that issue.

2. Whether defendants are entitled to JMOL that claim 1 of the ’140 patent is invalid, or that products with LT2600 chips do not infringe that patent.

3. Whether plaintiffs’ damages evidence was inadmissible and insufficient to support damages.

STATEMENT OF THE CASE

LED tube lamps have been sold since at least 2014. Appx10097 (194:23-25). They resemble older fluorescent lights and operate in fluorescent light fixtures, but produce light using energy-efficient light-emitting diodes instead of excited gas. *See* Appx10060 (45:4-15).

Plaintiffs Jiaxing Super Lighting Electric Appliance Co. *et al.* (“Super”) accused defendants CH Lighting Technology Co. *et al.* (“CH”) of infringing several LED tube-lamp patents. Appx1008-1046. CH disputed validity and infringement. Appx1051-1061.

Super argued that the three patents-in-suit, which have 2015 priority dates, cover minor differences from prior art. Two of them, U.S. Patent Nos. 10,295,125 (“the ’125 patent”) and 10,352,540 (“the ’540 patent”), propose attaching the LED strip or light-diffusion film directly to a lamp’s tube. The third, U.S. Patent No. 9,939,140 (“the ’140 patent”), discloses a shock-protection system that supposedly reverses the order of operations from prior technologies. Super’s internal documents indicate a policy of foreclosing competition by patenting “what is typically considered to be unpatentable." Appx20083. CH's experts testified that each asserted claim is anticipated or obvious.

I. THE ASSERTED PATENTS

A. The '125 Patent: Disposition of LED Strip on Lamp Tube's Inner Surface

Issued in May 2019 with a February 12, 2015 priority date, the '125 patent relates to attaching the LED strip within the lamp tube. Appx10178(282:12-18); Appx193. Asserted claim 1 recites a standard LED tube lamp—with end caps, power supply, and protective layer on the LEDs—where the LED light strip is disposed on the tube's "inner circumferential surface." It reads:

1. An LED tube lamp, comprising:

[a] a lamp tube;

two end caps, each of the two end caps coupled to a respective end of the lamp tube;

a power supply disposed in one or two end caps;

[b] ***an LED light strip disposed on an inner circumferential surface of the lamp tube***, the LED light strip comprising a mounting region and a connecting region, the mounting region for mounting a plurality of LED light sources, the connecting region having at least two soldering pads, and the mounting region and the connecting region being electrically connected to the plurality of LED light sources and the power supply; and

[c] a protective layer disposed on a surface of the LED light strip, the protective layer having a plurality of first openings to accommodate the plurality of LED light sources and at least two second openings to accommodate the at least two soldering pads.

Appx289 (lettering and emphasis added).

The only element Super asserted as novel was limitation 1[b]: "dispos[ing]" the "LED light strip . . . on an inner circumferential surface of the lamp tube." Appx10178 (284:15-19). Super contended that the '125 patent departed from prior art by using a flexible printed circuit board to affix an LED strip directly to the lamp's tube. Appx10098 (197:6-198:10). Super did not invent flexible LED strips, which date to 2005, Appx20008 n.1, and the patent encompasses LED strips mounted on a "hard circuit board," Appx258 (37:9-10).

B. The '540 Patent: Disposition of Diffusion Film on Lamp Tube

The '540 patent issued in July 2019 and has a priority date of February 12, 2015. Appx10181 (293:25-294:5); Appx292. Asserted claim 13 recites an LED light tube like that in the '125 patent, while adding a "diffusion film" for scattering light disposed on the lamp tube. Claim 13 reads:

> 13. An LED tube lamp, comprising:
>
> [a] a tube, comprising:
>
> a main body; and
>
> two rear end regions respectively at two ends of the main body;
>
> [b] two end caps respectively sleeving the two rear end regions, each of the end caps comprising:
>
> a lateral wall substantially coaxial with the tube, the lateral wall sleeving the respective rear end region;

an end wall substantially perpendicular to the axial direction of the tube; and

two pins on the end wall for receiving an external driving signal;

[c] ***an LED light strip disposed on an inner circumferential surface of the main body*** with a plurality of LED light sources mounted thereon;

[d] a power supply comprising a circuit board and configured to drive the plurality of LED light sources, the circuit board disposed inside one of the rear end regions and one of the end caps;

[e] an adhesive disposed between each of the lateral wall and each of the rear end regions; and

[f] ***a diffusion film disposed on the glass lamp tube*** so that light emitted from the LED light sources passing through the inner surface of the glass lamp tube and then passing through the diffusion film on the glass lamp tube.

Appx317 (lettering and emphasis added).

Super again urged that the prior art did not disclose "an LED light strip disposed on an inner circumferential surface" (limitation 13[c]). Appx10181 (294:14-20, 296:9-19). It also contended that claim 13 innovated by gluing "diffusion film" to the lamp tube (limitation 13[f]). Appx10181 (294:14-20); Appx10182 (297:25-298:22). Everything else was concededly in the prior art.

Dependent claim 14 adds that "a portion of the circuit board, one of the rear end regions, the adhesive and one of the lateral walls" of the end cap are "stacked sequentially in a radial direction," Appx317—that is, going from the center of the tube to the outside. According to Super, the prior art lacked that limitation. Appx10182 (298:23-299:23).

C. The ’140 Patent: Shock Protection

Issued in April 2018, the ’140 patent has a priority date of August 26, 2015. Appx141-142. Asserted claim 1 recites an “installation detection circuit” that attempts to avoid unintended shocks by engaging the main circuit only when the lamp is properly installed. It reads:

> 1. An installation detection circuit configured in a light-emitting diode (LED) tube lamp configured to receive an external driving signal, the installation detection circuit comprising:
>
> a pulse generating circuit configured to output one or more pulse signals; wherein the installation detection circuit is configured to detect during at least one of the one or more pulse signals whether the LED tube lamp is properly installed on a lamp socket, based on detecting a signal generated from the external driving signal; and
>
> a switch circuit coupled to the pulse generating circuit, wherein the one or more pulse signals control turning on and off of the switch circuit;
>
> wherein the installation detection circuit is further configured to:
>
> ***when it is detected*** during one of the one or more pulse signals ***that the LED tube lamp is not properly installed*** on the lamp socket, ***control the switch circuit to remain in an off state*** to cause a power loop of the LED tube lamp to be open; and
>
> when it is detected during one of the one or more pulse signals that the LED tube lamp is properly installed on the lamp socket, control the switch circuit to remain in a conducting state to cause the power loop of the LED tube lamp to maintain a conducting state,

> wherein the signal generated from the external driving signal is a sampling signal on the power loop, the installation detection circuit further comprises a detection determining circuit configured to detect the sampling signal for determining whether the LED tube lamp is properly installed on the lamp socket, and the power loop includes the switch circuit and the detection determining circuit, and
>
> wherein the pulse generating circuit is configured to output one or more pulse signals independent of whether the detection determining circuit detects the sampling signal.

Appx188-189 (emphasis added). The other asserted claims (4, 5, 24, 28, 31) recite the same basic elements with additional limitations. Appx188-192; Appx10165(231:2-232:21).

Super asserted that the '140 patent's shock-protection system differed from prior art because it turns on the main power switch ***before*** verifying proper installation, so that users receive small shocks if they install the lamp improperly. Appx10076(109:22-110:14). Super never reconciled that theory with claim language providing that the lamp "***remain*** in an off state" when the system detects "the LED tube lamp is not properly installed." Appx189(59:10-13) (emphasis added).

II. Procedural History

Before trial, both sides narrowed their contentions. Super dropped five of the eight patents it originally asserted, leaving the three described above. Appx1107. For the asserted patents, CH dropped its inequitable-conduct defenses and agreed to focus on invalidity, stipulating to infringement for all accused products except those with "LT2600" chips (including LT2600G) manufactured by Lumixess. Appx1107.

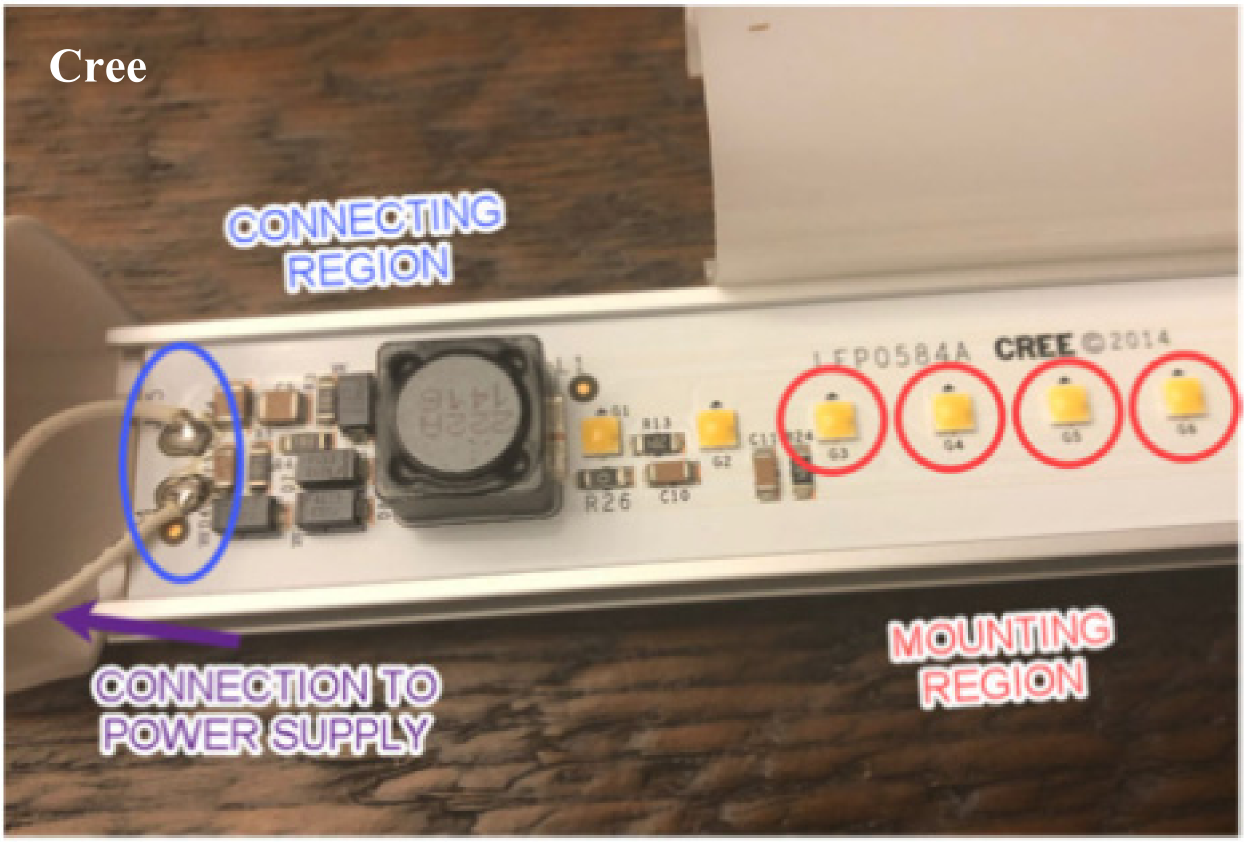
A. The District Court's Mid-Trial Grant of JMOL to Super on Invalidity of the '125 and '540 Patents

The '125 and '540 patents concern LED lamps' structure—where the LED strip and diffusion film are placed. CH's expert, Dr. Lebby, testified that the claims are invalid in light of three LED tube-lamp products sold before the patents' 2015 priority date: (1) Cree LED T8-48-21L-40K ("Cree tube"), (2) MaxLite G Series L18T8DF440-G ("MaxLite tube"), and (3) Philips InstantFit LED T816.5W/3500 ("Philips tube"). Appx10176(274:13-291:18); Appx21150-21176. Dr. Lebby testified—based on examination of the tubes, specification sheets, documentation, and markings—that each tube was on sale in 2014 and thus qualified as prior art. Appx10178(282:12-23) (Cree); Appx10179(285:20-24) (MaxLite); Appx10180 (289:18-23), Appx10186(315:21-23) (Philips); Appx10180(291:10-14); Appx10187(317:24-318:17); *see* Appx20054, Appx20063. Super never moved to exclude his testimony under *Daubert* or otherwise. Appx319-366.

1. *Claim 1 of the '125 Patent: LED Strip Disposition*

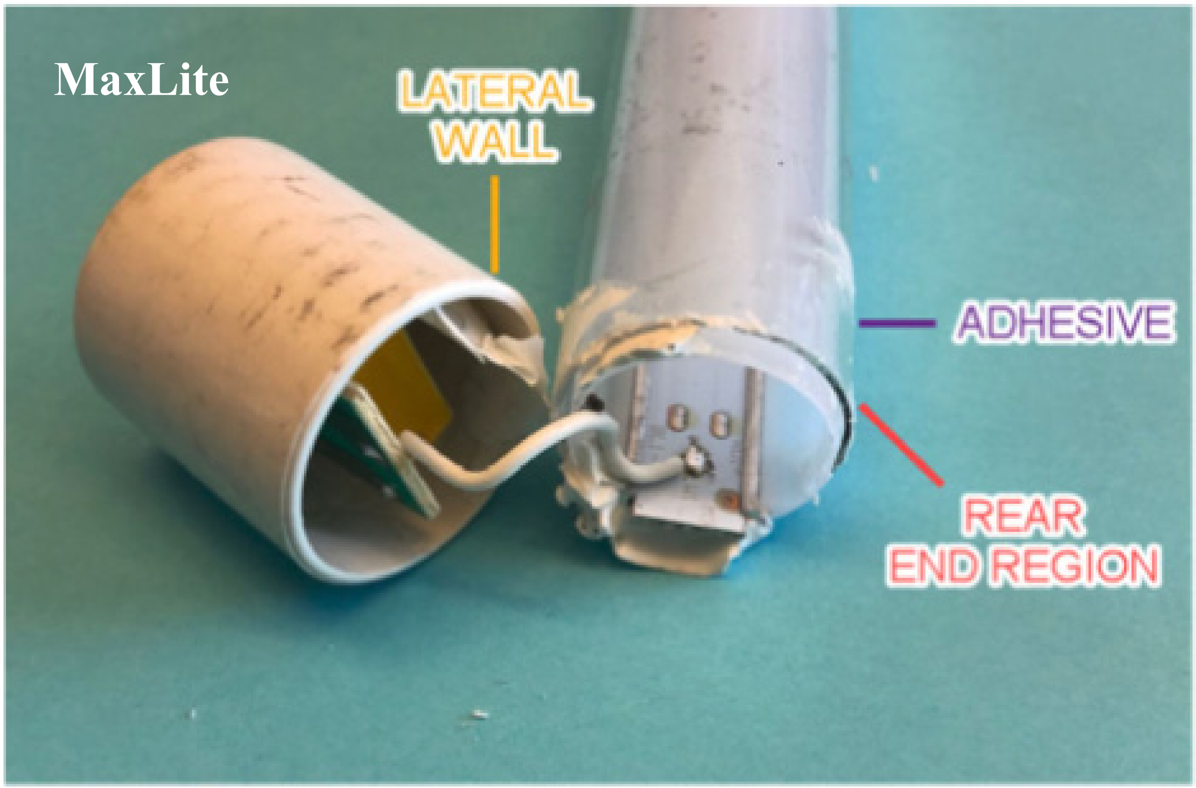
Super conceded that the Cree, MaxLite, and Philips LED tube lamps satisfied nearly every limitation of claim 1 of the '125 patent. Appx10177-10178(279:17-281:5). The sole dispute was whether the LED strip in those lamps was "disposed on an inner circumferential surface of the lamp tube." Appx10177-10178(280:19-281:5). Dr. Lebby testified that the lamps satisfied that limitation. Appx10177-10178(280:19-281:5); Appx10178-10179(284:15-285:10); Appx10179(287:5-

17).[1] His demonstrative photographs—depicting the units he considered when forming his opinions—showed LED strips directly touching, and thus "disposed on," the tube of each lamp:

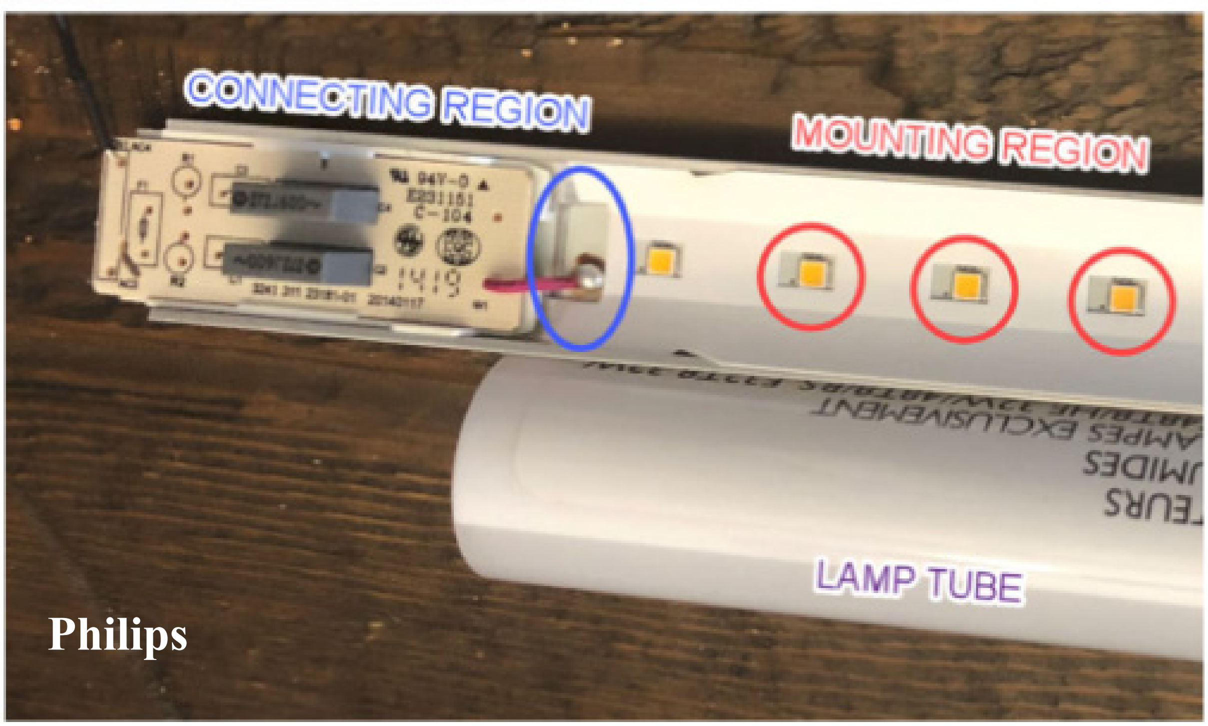


Appx21156 (annotated).

[1] Dr. Lebby testified that the Cree and MaxLite tubes satisfied all of claim 1's limitations, anticipating the claim, while the Philips tube satisfied all limitations except for two that Super did not dispute would have been obvious. Appx10177-10180(279:18-289:25).



Appx21196 (annotated).



Appx21172 (annotated).

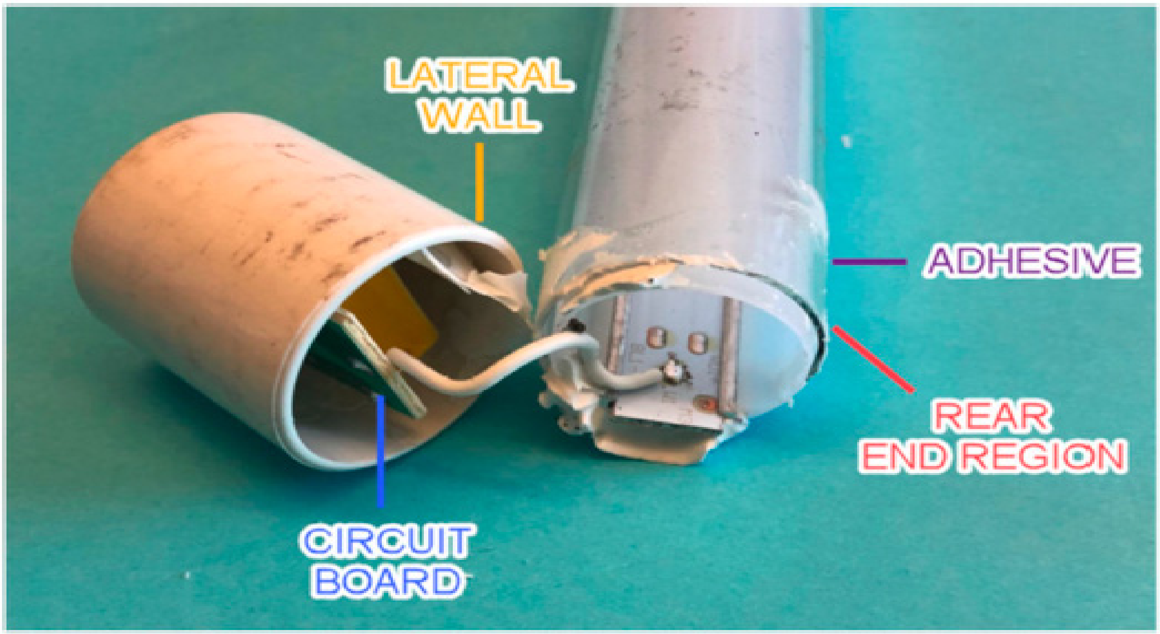
2. *Claims 13 and 14 of the '540 Patent: Diffusion Film*

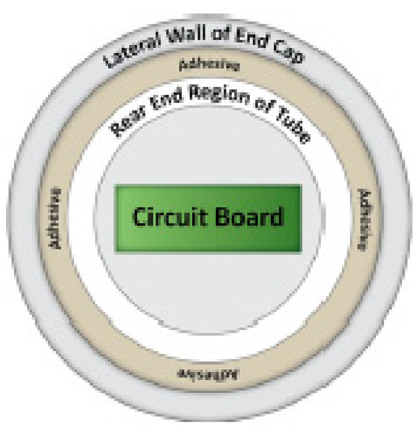
For claim 13 of the '540 patent, Super urged that the prior art lacked a "diffusion film" "disposed on" the lamp tube. Appx10226-10227 (109:22-113:20). Diffusion film is "a film that diffuses light," creating a "frosting effect." Appx10180 (292:6-20). Diffusion films were not "new," and could be found in "diffuse sticky tape" where you "can't see through it, but it allows light to go through." Appx10180 (292:15-20). The MaxLite tube, Dr. Lebby explained, had diffusion film affixed to its inner circumferential surface. Appx10181 (296:7-19); Appx10182 (298:3-14); Appx21194-21197. Insofar as the claim required the film to be on the outer surface—something Super's expert conceded would make no difference in performance—Dr. Lebby explained that such a trivial change would have been obvious. Appx10182 (298:1-22); Appx10098 (197:6-198:13).[2]

Super also invoked claim 14's requirement that the circuit board, tube, adhesive, and lateral wall of the end cap be stacked "sequentially in a radial direction," Appx317 (18:47-50), *i.e.*, with those four components arranged, in order, from the inside of the tube to its outer limit. Dr. Lebby testified that the MaxLite

[2] Super disputed whether prior art disclosed an LED strip disposed on the tube's "inner circumferential surface." Appx10226-10227 (109:22-113:20). That limitation was satisfied, Dr. Lebby testified, for the reasons he discussed regarding the '125 patent's virtually identical limitation. Appx10178 (284:17-285:10); Appx10181 (296:9-19); pp. 9-11, *supra*.

lamp stacked those components in the same order, again illustrating with demonstrative photographs and diagrams. Appx10182 (299:2-23).





Appx21199 (excerpts).

3. *The District Court Excludes the Physical Prior-Art Tubes and Related Documents*

The district court excluded from evidence the physical prior-art tubes and documentation Dr. Lebby examined.

Physical Prior-Art Tubes. The district court refused to admit into evidence the physical tubes on which Dr. Lebby based his opinions. Appx10111 (15:1-16:11); Appx10210 (46:18-20). It did not dispute those tubes were the "exact prior art products" Dr. Lebby examined when preparing his opinions. Appx10210 (45:3-46:10). The tubes' distinguishing features (such as distinctive grooves and slight damage) allowed Dr. Lebby to confirm they were the same; Super raised "no genuine objections" to authenticity. Appx10210 (45:3-46:11).

The court nonetheless held that Dr. Lebby could not sponsor the tubes' admission because, in light of the pandemic, he had examined them by videoconference and photographs rather than in person. Appx10111 (15:1-16:11); Appx10051 (11:9-12). The court did not address CH's alternative argument that the tubes' trade inscriptions made them "self-authenticating" under Federal Rule of Evidence 902(7). Appx10210 (45:3-46:10); *see* Appx10115 (31:14-18). On post-judgment motions, however, it declared the argument "waived." Appx68.

MaxLite Documents. CH sought to admit MaxLite business records confirming that the MaxLite tube was sold in 2014, before the patents' priority date. Appx1189-1190 (MaxLite specification and order sheet "[r]evised: 08-21-14"). CH's pretrial disclosures identified two authenticating witnesses, MaxLite employee Umesh Baheti and a potential alternate "MaxLite Representative." Appx21285-21287. MaxLite designated Mr. Baheti as its corporate representative; Super deposed him; and CH intended to call him at trial. Appx1206-1207 (4:14-5:7). The district court then moved the trial from October 18 to November 1, 2021, which coincided with Diwali—a major holiday in Mr. Baheti's faith—rendering him unable to attend. Appx1202; Appx1206-1207 (4:16-5:10).

CH proposed multiple solutions. Mr. Baheti could authenticate the documents shortly before or after trial. Appx1207 (5:20-25); Appx1212 (25:16-20). Or the alternate MaxLite representative, Eric Marsh, could testify during the new trial dates. Appx1202-1204; Appx1207 (5:8-15). The district court initially stated that, given Mr. Baheti's religious conflict, it did not "have an issue with the introduction of [the alternate] witness" to authenticate the documents. Appx1200. Absent proof of "real and substantial prejudice," the court was "unlikely to change course." Appx1200.

The court then changed course. Despite CH's disclosures identifying Mr. Baheti as a MaxLite witness (in addition to the potential "MaxLite Representative"), Appx21285-21287, identifying the MaxLite documents as exhibits, Appx1196; Appx1208 (10:6-13); Appx1181, and Super having deposed Mr. Baheti, Appx1182 n.1, the court declared that CH "failed to provide notice to Plaintiffs during discovery that Mr. Umesh Baheti would be authenticating MaxLite documents." Appx68-69. The court therefore precluded both Mr. Baheti and Mr. Marsh from authenticating those documents. Appx68-69; *see* Appx355 (Oct. 27, 2021 Order). The court cited no rule or order requiring parties to identify the documents each witness would authenticate. Nor did it deny that ***Super's*** disclosures failed to identify what documents each witness would authenticate. *See* Appx21288-21325; Appx1208 (9:20-10:13).

Super's Prior-Art Presentation. CH sought to admit a 2014 internal Super presentation tearing down Phillips and Cree LED tube lamps nearly identical to those Dr. Lebby examined, Appx20068-20081, confirming they were publicly available before the asserted patents' priority date. Appx10049-10050 (4:4-5:19). Excluding the presentation, the court declared that, although it "may invalidate the patent," the presentation was irrelevant because it purportedly pertained "only" to "inequitable conduct." Appx10050 (5:15-19, 7:12-16).

4. *Partial JMOL on Invalidity*

Following Dr. Lebby's testimony, the district court granted Super partial JMOL on invalidity under Rule 50(a), precluding CH's product-based invalidity defenses to the '125 and '540 patents from reaching the jury. Appx356 (Dkt. 221); Appx10212 (53:1-53:9). The district court did not deny that Dr. Lebby testified that the Cree, Philips, and MaxLite tubes were prior art, satisfied all limitations of the asserted claims, and rendered the claims obvious or anticipated. *See* pp. 9-13, *supra*; Appx10175-10185 (271:22-309:14). And the court acknowledged that Dr. Lebby based his testimony on the "kinds of facts and data" on which "experts in the particular field would reasonably rely," Fed. R. Evid. 703, such as examination of the tubes (through videoconference and photographs) and supporting technical documents. Appx10211 (49:20-50:16).

But the court held that Dr. Lebby's testimony that the Cree, MaxLite, and Philips tubes were prior art was insufficient, because the facts and data on which he relied were not themselves "admitted" as evidence "in the record" at trial. Appx10217-10219 (73:18-82:1); Appx10210-10212 (48:24-53:9). Dr. Lebby, the court stated, could rely on such information only "as long as it's admitted, as long as the evidence is in the record." Appx10217 (76:17-18). It rejected CH's contention that Rule 703 permits experts to rely on such information even when it is ***inadmissible***, foreclosing any requirement that such evidence be ***admitted***. Appx10218-10219 (80:25-81:23); Appx10215 (65:13-15). The court recognized that, if admitted, the excluded invalidity evidence would have defeated JMOL. Appx10217 (74:15-76:18); Appx10211-10212 (52:1-53:5).

After trial, the PTO ordered *ex parte* reexamination of the '125 and the '540 patents, including the claims asserted here. Appx22049; Appx22070. Examiners have now rejected all asserted claims of those patents as obvious. Appx22047-22066; Appx22067-22106.

B. Evidence Concerning the "Shock Protection" '140 Patent

CH contested the validity of claim 1 of the '140 patent, and whether accused products with LT2600 chips infringe that patent.

1. CH's expert, Dr. Zane, testified that International Patent Application WO 2012/066822—"Ono"—disclosed each limitation of claim 1. Appx10156-10160(193:1-209:10). All agreed that Ono is prior art and that it discloses a pulse generating circuit, switch circuit, installation detection circuit that generates power only during proper installation, and sampling signal that identifies whether the lamp is properly installed. *Compare* Appx10019 *with* Appx188-189(58:61-59:32); *see* Appx10156(193:11-24); Appx10221(90:13-22). They disagreed whether Ono's pulse generating circuit controls the "switch circuit," and specifically turns it from "on" to "off," which Super urged claim 1 requires. Appx10221(90:13-92:2).

Dr. Zane testified that Ono satisfies that purported limitation. Appx10156-10158(196:19-204:25); Appx10000-10033. As he explained, Ono has a "signal output circuit" that "outputs a voltage signal," such as "a rectangular pulse." Appx10014(¶47); Appx10157(197:1-22). That pulse can be used to "determine[] whether there is an open state or a shorted state" between the terminals, *i.e.*, whether the tube lamp is properly installed. Appx10014-10015(¶51). If the lamp is not properly installed, the "control circuit" will "switch the switch . . . from the ON state to the OFF state," preventing shocks. Appx10013(¶¶42, 44); Appx10158(202:12-203:4); Appx21496-21498.

Super's invalidity expert, Dr. Phinney, testified that Ono follows "the old way with respect to shock protection," "the opposite of what the '140 patent does."

Appx10221 (90:13-22). Although the plain language of claim 1 does not require any specific order of operations, *see* Appx189 (59:13-14), Dr. Phinney sought to distinguish Ono on the ground that Ono ***first*** detects whether "installation is proper" and only ***later*** activates the circuit, whereas the '140 patent "goes right ahead and turns on the light ***first*** and ***then*** determines if there's a proper installation." Appx10221 (90:23-91:5) (emphasis added). Dr. Phinney further testified that the '140 patent uses pulses of voltage to turn on the switch circuit, whereas Ono used voltage pulses to "query" installation but relied on a "detection" of "impedance"—a "response" to the pulse—to turn on the switch circuit. Appx10221 (91:6-22).

2. CH argued that products with LT2600 chips did not infringe the '140 patent. Like Ono, those chips use impedance—not voltage alone—to detect proper installation and prevent shocks. Appx10034-10039; Appx10166-10167 (236:1-238:10); Appx10095 (186:21-187:6). Lumixess, the chips' manufacturer, had its own "patented grid ***impedance*** measured algorithm" in the chips. Appx10034 (emphasis added).

Super's infringement expert, Dr. D'Andrade, confirmed that the LT2600 chips follow the sequence Dr. Phinney described as the "old way": "[I]t's making a determination, is someone touching, ***stay off***. If no one is touching, it's properly installed, ***turn on***." Appx10095 (186:21-187:6) (emphasis added).

3. CH moved for JMOL, arguing that Ono anticipated claim 1. Appx10215-10216 (67:22-71:10). Alternatively, it argued noninfringement. Appx10132-10133 (100:14-102:7); Appx10215 (66:5-67:18); Appx20018-20020. Super, CH explained, could not argue that ***Ono's*** detection of impedance made it ***patentably distinct*** from the '140 patent, while simultaneously arguing that ***accused products'*** detection of impedance renders them ***infringing*** of the '140 patent.

The district court denied the motions, without addressing the contradiction between Super's invalidity and infringement positions. Appx10132-10133 (100:14-102:7); Appx10215-10216 (67:22-71:10).

C. Damages Evidence

Super's damages expert, Ms. Kindler, proposed a per-unit royalty based on two portfolio licenses Super had with Technical Consumer Products ("TCP") and Lunera Lighting. Appx21340-21346; Appx21326-21339.

The district court denied CH's *Daubert* motion to exclude Ms. Kindler's testimony. Appx1119 (27:14-16); Appx353-354 (Dkt. 190). CH had argued that Ms. Kindler failed to "properly account for differences" between those licenses and a hypothetical negotiation over the asserted patents. Appx1094-1099. For example, the TCP and Lunera licenses covered Super's entire portfolio of 260+ patents, not just the three patents-in-suit. Appx1095; Appx1099. Ms. Kindler did not adjust the royalty rates to reflect that difference. Instead, her proposed $0.30-$0.45/unit royalty was equal to or ***greater*** than Lunera's and TCP's royalties. Appx10123 (61:15-20); Appx10122 (57:22-59:16); Appx10193-10194 (344:6-346:6); Appx1098-1099; Appx10126-10127 (76:24-77:8). Her proposed royalty, moreover, did not depend on whether a product infringed the '140 patent (shock protection), the '125 and '540 patents (disposition of LED strips and diffusion film), or all three.[3]

Super entered the Lunera agreement in 2016, Appx10122 (58:3-13), more than a year before any asserted patent issued. Lunera, a wholesaler like CH, agreed to pay a 5% royalty on its wholesale price. Appx10122 (57:22-59:16); Appx10193-10194 (344:6-346:6). Ms. Kindler applied Lunera's 5% ***wholesale*** royalty to ***retail*** prices for Lunera products she found online in 2021 to achieve a per-unit royalty of $0.35-$0.45. Appx10122 (58:20-60:19); Appx10129-10130 (87:6-90:4). That amounted to ***10.8% to 13.9%*** of CH's actual ***wholesale*** price, where Lunera had paid ***5%***. Appx10132 (97:3-98:2). The TCP agreement, entered into during this litigation in 2021, included a $0.30/unit royalty. Appx10123 (61:15-20).

Ms. Kindler asserted that, while the TCP and Lunera licenses covered Super's entire 260+ patent portfolio, setting royalties for a single patent at the portfolio

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[3] Five million accused units, sold before the '125 and '540 patents issued, could infringe only the '140 patent. Appx10126 (75:18-21). Another "17 product codes," totaling 6.2 million units, were accused of infringing only the '125 and '540 patents. Appx10126 (74:10-17).

rate—or 50% above it—was justified because "Super Lighting personnel" told her the asserted patents were "very important." Appx10122-10123 (60:20-61:5).

For the TCP license, Ms. Kindler testified that she reviewed a Super document—not admitted into evidence—that putatively showed "a subset of patents . . . drove" the TCP "negotiation and the final terms." Appx10121 (53:23-54:25). That document listed the '140 patent along with thirteen other patents ***not*** asserted at trial. Appx21731-21733. It did not list the '125 and '540 patents. Ms. Kindler asserted that some listed patents were "substantially similar" to those patents, Appx10121 (54:10-25), but conceded she was not a technical expert, had not examined the patents, and simply relied on what Super (not its expert) told her. Appx10129 (86:17-87:4).

D. Willfulness

Urging willful infringement, Super's counsel hammered on CH's stipulation to infringement. In "almost 25 years," he told the jury, he had "never" seen that. Appx10054 (23:16-24:1). In fact, Super's counsel had been involved in litigation where defendants stipulated not only to "infringement," but also "validity" and "enforceability." Appx21712-21713. Super also highlighted a privileged email from CH's prior counsel advising CH on possible strategies—such as insisting, as a Chinese national, on proper service under international law—that could avoid or delay litigating in Texas. Appx10040-10048. Super insisted that showed a lack of "legitimate defenses." Appx10252 (35:4-15); Appx10254 (43:17-20).

E. The Verdict and Post-Trial Motions

Finding for Super on infringement, invalidity, and willfulness, the jury awarded $13,872,872 against CH Lighting and $298,454 against its distributor (Elliott)—exactly matching Ms. Kindler's upper-end royalty figure of $0.45/unit. Appx135-140; Appx10119 (46:14-47:15). The district court enhanced damages for certain periods to $0.90/unit, Appx22; Appx91-93, and awarded a $0.45/unit ongoing royalty, Appx89-91.

CH sought a new trial, challenging the grant of partial JMOL on invalidity, evidentiary rulings, trial conduct, and Ms. Kindler's damages testimony. Appx20031-20050. CH also renewed its JMOL motions. Appx20004-20024; *see* Appx10132-10133 (100:14-102:7), Appx10215-10216 (67:21-71:9) (Rule 50(a) motions). Among other things, CH urged that Ms. Kindler's methodology contravened three decisions issued after CH's *Daubert* motion: *Apple Inc. v. Wi-LAN Inc.*, 25 F.4th 960, 973-74 (Fed. Cir. 2022), *Omega Patents, LLC v. CalAmp Corp.*, 13 F.4th 1361, 1381 (Fed. Cir. 2021), and *MLC Intellectual Property, LLC v. Micron Technology, Inc.*, 10 F.4th 1358, 1373 (Fed. Cir. 2021). Appx20042-20047.

Super's opposition did not address or cite *Wi-LAN*, *Omega*, or *MLC*. *See* Appx21570, Appx21588-21590. The district court ordered supplemental briefing on *Wi-LAN*, *see* Appx72, then denied CH's post-judgment motions, Appx46-94. The court's rationale for rejecting CH's challenge to Ms. Kindler's damages methodology reproduces four pages of Super's supplemental brief verbatim. *Compare* Appx74-76 *with* Appx21736-21740.[4] Its opinion never addresses *Omega* and *MLC*, which CH invoked, Appx20042-20047; Appx21725-21728, but Super ignored.

SUMMARY OF ARGUMENT

I.A. The grant of partial JMOL on invalidity must be reversed. Dr. Lebby's expert testimony was substantial evidence from which the jury could find the '125 and '540 patents invalid: He testified that prior-art products satisfied every limitation and were publicly available before the priority date. That testimony was supported by the facts and data he considered. This Court and others have repeatedly held such testimony sufficient to defeat JMOL.

The district court's contrary view—that expert testimony is sufficient only if the facts and data on which the expert relied are admitted into evidence—is wrong. Rule 703 does not require supporting facts and data to be ***admissible***, much less ***admitted***. Rule 703 refutes the court's contention that Dr. Lebby needed "personal knowledge." And nothing required that Dr. Lebby physically handle the prior-art tubes he considered.

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[4] Where Super's supplemental brief contained a footnote, the opinion deletes the footnote's substance but not the footnote's call in text. *Compare* Appx73 ("Doro.1") *with* Appx21736.

B. The district court erroneously excluded the prior-art tubes underlying Dr. Lebby's invalidity opinions. The tubes were plainly relevant and authentic. The court's rationales for exclusion—that the tubes were not produced in discovery and that Dr. Lebby did not personally examine them—were factually and legally incorrect. Regardless, the tubes were self-authenticating under Rule 902(7); the court's assertion of waiver was unfounded.

The district court erroneously excluded documents confirming the Max-Lite tube was on sale before the priority date by excluding any sponsoring witness. It refused to accommodate the religious observance of CH's anticipated witness. It asserted noncompliance with a nonexistent disclosure requirement that Super was never held to. It also failed to consider that any putative nondisclosure was substantially justified by the changed trial date and the witness's religious conflict, and that Super would suffer no prejudice.

The 2014 Super presentation—which showed Super possessed tubes from the same product lines Dr. Lebby considered—should have been admitted. That document showed the products were publicly available before the 2015 priority date. Any difference in wattages was immaterial to invalidity and did not render the presentation ***irrelevant***.

C. The '125 and '540 patents are anticipated or obvious. The prior-art tubes showed that skilled artisans had already made the patents' claimed improvements.

Any changes were so trivial as to be obvious. The PTO has rejected the asserted claims in reexamination.

II. Super's attempt to twist claim 1 of the '140 patent like a "nose of wax" requires judgment of invalidity or noninfringement.

A. Ono anticipates claim 1. Super distinguished Ono on the ground that Ono requires first detecting proper installation and then turning on the switch, whereas the '140 patent purportedly requires first turning on the switch and then detecting proper installation. But Ono's disclosure encompasses both, as does claim 1's plain language.

Super also distinguished Ono because it uses detection of impedance, rather than voltage, to control the switch. But claim 1 is not limited to measuring a specific electrical property; it encompasses detection of impedance.

B. Alternatively, products with LT2600 chips do not infringe the '140 patent. Like Ono, those chips use detection of impedance to control the switch. If that feature makes Ono non-anticipating as Super contends, it also makes LT2600-chipped products non-infringing.

III. A. Super's damages evidence failed to apportion. It did not account for crucial differences between Super's 260-patent portfolio licenses and a hypothetical negotiation over the three patents-in-suit. Rather than apportion the portfolio rates downward to reflect the three asserted patents, she proposed (and the jury adopted) royalties ***greater*** than the portfolio rates. And she calculated the same royalty regardless of which patents a product allegedly infringed.

B. Rather than follow *Wi-LAN*'s, *Omega*'s, and *MLC*'s apportionment requirements, the district court copied verbatim Super's supplemental brief—which misconceived *Wi-LAN* and never mentioned *Omega* or *MLC*. The court's effort to deny the prejudice is unsustainable. And its parroting of Super's preservation objections defies the law and the record.

ARGUMENT

CH is entitled to a new trial—if not judgment—on three grounds. First, the district court erroneously granted JMOL on invalidity of the '125 and '540 patents. The court did not merely exclude highly relevant, admissible evidence of invalidity, including the physical tubes and documents CH's expert considered. It embraced the legally unsustainable notion that expert testimony cannot support a jury finding unless the facts and data on which the expert relied are admitted into evidence. That contradicts Rule 703's directive that the facts and data on which an expert relies need not even be admissible—*a fortiori*, they need not be actually admitted.

Second, the verdict with respect to the '140 patent rests on irreconcilable positions. Opposing invalidity, Super urged that a prior-art reference's use of impedance ***distinguished*** it from the '140 patent. But when pressing infringement, Super urged that the accused products' use of impedance ***infringed*** the '140 patent. Super cannot twist the claims one way for invalidity and another for infringement.

Third, Super's damages evidence was woefully deficient. It failed to account for differences between Super's 260-patent portfolio licenses and a hypothetical negotiation over the three patents-in-suit. Super's expert proposed, and the jury awarded, a ***greater*** royalty for any ***one*** of the patents-in-suit than Super ever received for its ***entire portfolio***. A more egregious failure to apportion is hard to imagine.

Standard of Review. Under Fifth Circuit law, JMOL is reviewed *de novo*, and is permissible only where "'"there is no legally sufficient evidentiary basis for a reasonable jury to find"'" for the non-moving party. *ACCO Brands, Inc. v. ABA Locks Mfr. Co.*, 501 F.3d 1307, 1311 (Fed. Cir. 2007). Evidentiary rulings and denial of new-trial motions are reviewed for abuse of discretion; a district court necessarily abuses its discretion where its decision rests on an erroneous view of the law. *Jordan v. Maxfield & Oberton Holdings, L.L.C.*, 977 F.3d 412, 417 (5th Cir. 2020); *Elbit Sys. Land & C4I Ltd. v. Hughes Network Sys., LLC*, 927 F.3d 1292, 1299 (Fed. Cir. 2019).

I. The District Court Erred In Granting JMOL For Super On Invalidity Of The '125 And '540 Patents

The district court granted partial JMOL on invalidity—preventing the jury from considering CH's defense that prior-art products invalidate the '125 and '540 patents—based on a cascading series of legal errors. The court refused to admit the physical tubes that CH's invalidity expert relied on, because he had examined the tubes via photographs and videoconference during the pandemic. No rule requires that evidence be physically handled by an expert to be admissible.

The court also excluded documents confirming the MaxLite tube was publicly available before the priority date. It refused to accommodate a conflict with the sponsoring witness's religious observance. It then refused to let an alternate witness authenticate the documents, invoking a nonexistent disclosure requirement that Super was never held to. And it excluded as "irrelevant" a document showing that Super itself possessed competitors' invalidating products before the priority date.

Having excluded all that evidence, the district court granted Super partial JMOL on invalidity. That ruling rested on yet another error. Although Dr. Lebby testified that the tubes he examined satisfy every limitation and were publicly available before the priority date, the court declared his testimony was insufficient unless supported by evidence "admitted" "in the record" at trial. But Rule 703 and precedent make clear that expert testimony is ***itself*** evidence that can sustain a verdict. The information on which the expert relies need not even be ***admissible***, much less ***actually admitted***.

A. Dr. Lebby's Testimony Was Substantial Evidence of Invalidity

Dr. Lebby testified that the Cree, MaxLite, and Philips tubes satisfied each limitation of the asserted claims of the '125 and '540 patents. *See* pp. 9-13, *supra*.

He also testified—based on the tubes, specification sheets, and documentation—that the tubes were prior art because they were on sale in 2014, before the patents' 2015 priority date. Appx10178(282:14-15) ('125 patent); Appx10181(294:2-3) ('540 patent); Appx10178(282:19-23) (Cree); Appx10179(285:20-24) (MaxLite); Appx10180(289:18-23) (Philips); *see* Appx10186-10187(315:21-318:17); Appx20063. He thus testified that those tubes invalidated each claim. Appx10178(283:2-3); Appx10179(286:3-4); Appx10180(289:16-17; 291:12-14); Appx10182(299:25-300:3).

1. That testimony was substantial evidence from which a reasonable jury could find invalidity, foreclosing JMOL for Super. Substantial evidence is "such relevant evidence as a reasonable mind might accept as adequate to support a conclusion." *Consolidated Edison Co. of N.Y. v. NLRB*, 305 U.S. 197, 229 (1938); *see Fonar Corp. v. Gen. Elec. Co.*, 107 F.3d 1543, 1551-52 (Fed. Cir. 1997). A reasonable jury plainly could have accepted Dr. Lebby's (indisputably relevant) testimony and concluded that the Cree, MaxLite, and Philips tubes were prior art that invalidated the asserted claims.

This Court and the Fifth Circuit have repeatedly held that "expert testi[mony]," by itself, constitutes "substantial evidence from which [a] jury could reasonably conclude" that the matters to which the expert testified are true. *ActiveVideo Networks, Inc. v. Verizon Comm'cns, Inc.*, 694 F.3d 1312, 1321 (Fed.

Cir. 2012) (affirming denial of JMOL based on expert testimony alone); *see Melancon v. Western Auto Supply Co.*, 628 F.2d 395, 399 (5th Cir. 1980) ("[I]n light of the testimony of appellant's expert witness, it was error for the trial court to direct a verdict for [appellees.]"); *Fonar*, 107 F.3d at 1551 (expert's testimony provided "substantial evidence to support the jury's finding"); *Bio Tech. Gen. Corp. v. Genentech, Inc.*, 267 F.3d 1325, 1330-31 (Fed. Cir. 2001) (reversing JMOL on invalidity because expert testimony supported contrary jury finding). Relevant and admissible expert testimony precludes JMOL on an issue because such "expert testimony [is] itself evidence." *Castillo v. Barr*, 980 F.3d 1278, 1284 (9th Cir. 2020).

2. The district court nowhere denied that Dr. Lebby testified that the tubes satisfied every relevant limitation and "were on sale in time to qualify as prior art." Appx66. But the court ruled Dr. Lebby's testimony "could not constitute sufficient evidence" because, in its view, expert testimony can support a jury verdict only if the facts and data on which the expert relied are ***themselves*** "admitted" "in evidence" at trial. Appx66-67; Appx10217 (76:17-18); *see* Appx10211 (50:4-52:25).

That is incorrect. Expert testimony alone is enough to defeat JMOL, because "expert testimony [is] itself evidence." *Castillo*, 980 F.3d at 1284; *see ActiveVideo*, 694 F.3d at 1321; *Melancon*, 628 F.2d at 399; *Fonar*, 107 F.3d at 1551; *Bio Tech.*, 267 F.3d at 1330-31. There is no requirement that expert testimony be bolstered through admission of ***additional*** evidence, including the facts and data the expert relied upon when forming his opinions. To the contrary, Rule 703 states that, where "experts in the particular field would reasonably rely on th[e] kinds of facts or data" an expert considered, those supporting facts and data "***need not be admissible*** for the opinion to be admitted." Fed. R. Evid. 703 (emphasis added). If supporting facts and data need not be ***admissible***, *a fortiori* they need not be actually ***admitted***.

Dr. Lebby's opinion rested on the kinds of facts or data on which invalidity experts would reasonably rely. It was based on "product specification sheet[s]" and other documentation from before the priority date, as well as markings on the tubes, including a "Cree ©2014" copyright. Appx10186-10187 (315:21-318:17); Appx21156; *see* Appx10177 (278:1-20); Appx10217 (75:24-76:6); Appx20052-20067 (expert report citing and excerpting documents underlying Dr. Lebby's opinion); Appx20162-20163 (materials considered); Appx21145-21224 (Lebby demonstratives); Appx1189-1190 (MaxLite 8/21/14 specification sheet); Appx20215 (MaxLite 12/23/14 specification sheet); Appx20256-20264; Appx20295-20296 (Philips 11/29/14 specification sheet and 2014 product sheet); p. 10, *supra* (photograph showing Cree 2014 copyright).[5]

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[5] Dr. Lebby's opinion that the tubes satisfied each claim limitation was similarly supported by detailed photographs of the tubes and an examination Dr. Lebby directed by videoconference. Appx10051 (11:9-12); Appx10111 (14:24-15:9); Appx10177 (278:13-20); Appx21145-21224.

The district court agreed those are the kinds of facts and data on which experts reasonably rely. Appx10211(49:20-50:6); Appx10217(76:5-18). Super's expert likewise relied on "data sheets," "technical schematics," and photographs. Appx10090(167:21-168:2). And this Court has held expert testimony that "relied upon the technical literature, specifications, and drawings" of relevant products sufficient to defeat JMOL. *Fonar*, 107 F.3d at 1551-52.

3. Denying the new-trial motion, the district court posited that Dr. Lebby lacked "personal knowledge" about the tubes' availability. Appx66. That too was legal error: Rule 602 exempts "expert testimony under Rule 703" from the requirement of "personal knowledge." Fed. R. Evid. 602. Under Rule 703, an "expert may base an opinion on facts or data in the case ***that the expert has been made aware of*** or personally observed." Fed. R. Evid. 703 (emphasis added). Here, Dr. Lebby was "made aware" of when the tubes were publicly available through his review of the tubes and documents, and "base[d his] opinion" on those facts and data.

Rule 702(b)'s requirement that expert opinions be " 'based on sufficient facts or data,' " Appx67, was amply satisfied. Dr. Lebby's opinion that the prior-art tubes invalidate the asserted claims—including his opinion that the tubes qualify as prior art—was based on the tubes and supporting documentation, as explained in his testimony, Appx10186-10187(315:21-318:17), and expert report, Appx20063(¶¶1004, 1006, 1008); *see* pp. 9-13, *supra*.[6] Tellingly, Super never moved to exclude Dr. Lebby under Rule 702(b) or *Daubert*, *see* Appx10176(273:22-274:1) (Dr. Lebby accepted as expert without objection); never objected to his testimony, Appx10176-10185(274:2-309:14) (testimony admitted without objection); and never argued that the documents he invoked failed to support his conclusions.

The district court objected that Dr. Lebby "could not point to a document ***in evidence*** that established they were on sale." Appx67 (emphasis added). That repeats the misconception addressed above. While expert testimony must be "based on sufficient facts or data," Fed. R. Evid. 702(b), those "facts or data . . . need not be admissible," Fed. R. Evid. 703, much less actually admitted into evidence.

4. The district court's post-trial accusation that Dr. Lebby offered " 'conclusory, unsupported assertions,' " Appx67 (quoting *Kampen v. Am. Isuzu Motors, Inc*., 157 F.3d 306 (5th Cir. 1998) (en banc)), lacks merit. Dr. Lebby explained the factual basis for his opinions in detail. *See* pp. 9-13, *supra*. His testimony does not remotely resemble the testimony held insufficient in *Kampen* (cited Appx67), where the expert (a metallurgist) gave "internally inconsistent" testimony on a subject for which he was "not qualified"—"the habits of users of automobile jacks" and "their propensities for disregarding explicit warnings." 157 F.3d at 318.

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[6] Dr. Lebby's opinions were further supported by a document showing that Super possessed relevant Cree and Philips tubes by August 2014. Appx10217(74:20-75:23); Appx20068-20081; *see* pp. 44-46, *infra*.

Even in *Kampen*, the court explained that the expert's testimony on topics ***within*** his expertise (*e.g.*, "the relative strength of the steel used" and "foreseeable *mechanical* uses") "would likely create a fact issue." 157 F.3d at 317-18. Here, Dr. Lebby has two doctorates in electrical engineering, over a decade's experience designing LED lights, and 230 U.S. patents, among other credentials. Appx10175-10176 (272:9-273:21). He was plainly qualified to testify that the LED light tubes he considered were prior art that invalidated Super's claims, and the jury reasonably could have credited that testimony.

The district court protested that "no reasonable jury could credit [Dr. Lebby's] invalidity theory," noting that Dr. Lebby "did not take the photographs, direct taking the photographs, [or] know who took the photographs" of the prior-art tubes that he used to form his opinions. Appx67. But that had no bearing on Dr. Lebby's ability to examine the photographs, conclude that the tubes satisfied each claim limitation, and explain his conclusions to the jury. The court never suggested the photographs did not support Dr. Lebby's opinions—it complained only that the photographs were not admitted "into evidence," Appx10211 (50:1-16), which was not required, *see* pp. 31-33, *supra*. And the assertion that Dr. Lebby did not "follow up on the physical items in the photographs," Appx67, is mistaken. Dr. Lebby directed an examination of the same physical tubes via Zoom videoconference, Appx10111 (15:8-11), allowing him to confirm the features observed in the photographs. The jury readily could have credited his testimony. The district court's contrary ruling rests on legal error and invades the jury's role.

B. The District Court Erred in Excluding Other Invalidity Evidence

The district court's erroneous JMOL ruling flowed from prior legal errors: Its exclusion of the physical tubes Dr. Lebby considered and documents confirming that the Cree, MaxLite, and Philips tubes were prior art. The court recognized that, if admitted, that evidence would have foreclosed JMOL. Appx10211(49:15-51:9); Appx10211-10212(52:1-53:5). Their erroneous exclusion affected "substantial right[s]" and requires a new trial. *In re Taxotere (Docetaxel) Prods. Liability Litig.*, 26 F.4th 256, 263 (Fed. Cir. 2022).

1. *The District Court Erroneously Excluded the Prior-Art Tubes*

When CH sought admission of the physical Cree, MaxLite, and Philips tubes Dr. Lebby considered, Appx10109-10112(6:4-17:15); Appx10210(45:12-46:17), the court did not dispute the tubes' relevance or authenticity, or that they were the exact specimens Dr. Lebby considered. It excluded the tubes nonetheless, under an evolving set of erroneous rationales.

<u>Supposed non-production or examination</u>. The court initially excluded the tubes because they supposedly "were not produced earlier," depriving Super of "a chance to depose" Dr. Lebby about them. Appx10111(14:5-8, 15:16-18); Appx10211(52:4-5) ("I excluded the tubes because the tubes had not been pro-

duced."). Post-trial, the court abandoned that rationale, *see* Appx67-68, because the tubes ***were*** produced and available for inspection by June 2020—before Super deposed Dr. Lebby in August 2021. Appx21229 n.1, Appx21232-21233, Appx21283; *see* Appx1218 n.1, Appx1221-1222, Appx1282; Fed. R. Civ. P. 34.

The court turned to another rationale—that Dr. Lebby "did not physically examine the tubes" and instead examined them through photographs and videoconference. Appx68; *see* Appx10110-10112(9:1-17:7). Dr. Lebby, the court asserted, "made 'a choice'" not "'to look at the bulbs themselves.'" Appx68. But no Federal Rule renders relevant, authentic objects inadmissible unless an expert touches them before trial. And Dr. Lebby ***did*** "look at the bulbs themselves"—the exact physical specimens CH sought to admit—when he examined them by photograph and videoconference. That he had not "touched" the tubes or viewed them with his "naked eye," Appx10110(10:1-11:5), could not make them irrelevant. As the very prior-art tubes that rendered the claims invalid—the precise items Dr. Lebby considered when assessing invalidity—the tubes were highly relevant. Nor did the nature of Dr. Lebby's previous examinations prevent him from authenticating the physical tubes as the items on which he based his opinions. Based on "distinctive groove marks" and "damage," Dr. Lebby had "total confidence that those [physical] tubes are the same tubes depicted in the photographs." Appx10110(11:18-12:1). Super never suggested otherwise. Appx21580-21581.

That Dr. Lebby was able to deliver his opinions without the physical tubes in evidence is no ground for exclusion. "Relevant evidence is admissible" unless some rule of evidence or law provides otherwise. Fed. R. Evid. 402. The district court identified no rule or law warranting exclusion. The tubes were not, for example, confusing or cumulative (especially given the district court's view that Dr. Lebby's testimony alone would be insufficient). *See* Fed. R. Evid. 403. Nor did (or could) the district court find Super would suffer "unfair prejudice." *Id.* The tubes were the exact specimens Dr. Lebby testified about at length without objection. And the notion that Super was unable to depose him about the physical tubes, *see* Appx10111 (15:16-18), is concededly mistaken. *See* pp. 36-37, *supra*.

Any suggestion that CH "abandoned using the tubes," Appx68 (citing Appx10111 (16:12)), is likewise unfounded. The cited exchange concluded with CH requesting and being allowed "an offer of proof with respect to the physical tubes," Appx10112 (17:14-16)—an offer it fulfilled, Appx10210 (45:3-46:22).

<u>Self-authentication</u>. The physical tubes were independently admissible as self-authenticating evidence. Under Rule 902(7), an "inscription, sign, tag, or label purporting to have been affixed in the course of business and indicating origin, ownership, or control" is "self-authenticating" and requires "no extrinsic evidence of authenticity." Fed. R. Evid. 902(7). Courts interpret that rule to mean that "the ***item*** to which the trade inscription is affixed is also authenticated under this

provision." 31 C. Wright *et al.*, *Federal Practice & Procedure* § 7141 (2d ed.) (emphasis added); *see Alexander v. CareSource*, 576 F.3d 551, 561 (6th Cir. 2009) (letter on company letterhead self-authenticating). Here, the physical tubes bore identifying trade inscriptions, and Super raised "no genuine objections" to authenticity. Appx10210 (45:17-22). They were accordingly admissible without a sponsoring witness or other "extrinsic evidence of authenticity." Fed. R. Evid. 902(7). The district court did not find otherwise.

After trial, the district court declared that CH "waived" its trade-inscription argument. Appx68. But CH objected to the tubes' exclusion and stated its desire to make an offer of proof "at a convenient time" for the court. Appx10112 (17:12-21). Both then and in its offer of proof the next day, CH stated that the tubes' "trade inscriptions" made them "self-authenticating" under Rule 907. Appx10210 (45:11-22); *see* Appx10115 (31:8-20). That is how parties ***preserve*** arguments about evidentiary error. Fed. R. Evid. 103(a); *Ultratec, Inc. v. CaptionCall, LLC*, 872 F.3d 1267, 1274 (Fed. Cir. 2017); *United States v. Kay*, 513 F.3d 432, 455 (5th Cir. 2007).

2. *The District Court Erroneously Excluded MaxLite Documents*

The district court erred in excluding business records showing the MaxLite tube was on sale in 2014, before the patents' 2015 priority date. *See* Appx20063; Appx1188-1190. Those documents, timely identified as anticipated trial exhibits, would have filled any perceived evidentiary gap regarding the MaxLite tube's status as prior art, making JMOL improper.

Sponsoring-witness disclosure. The district court excluded those documents based on CH's supposed failure to disclose a sponsoring MaxLite witness. That was error. CH's pretrial disclosures timely reported that CH intended to call MaxLite through a corporate representative. Appx21287. It identified two MaxLite witnesses: "Umesh Baheti (MaxLite)" and an alternate "MaxLite Representative." Appx21287. Mr. Baheti was deposed as MaxLite's corporate representative, Appx1206-1207 (4:14-5:19), and CH prepared him to testify at trial.

The court subsequently moved the trial to a date that "coincide[d] with Diwali, . . . a major religious holiday for Mr. Baheti." Appx1207 (5:8-10). To accommodate the changed trial schedule and Mr. Baheti's resulting unavailability, CH proposed multiple solutions: Mr. Baheti could authenticate the documents before or after the rest of the trial, or an alternate MaxLite representative (Eric Marsh) could testify solely to authenticate MaxLite documents CH already identified as trial exhibits. Appx1207 (5:8-25); Appx1212 (25:16-20); Appx1191-1205. The district court originally stated that it did "not have an issue with" CH's calling Mr. Marsh "for the sole purpose of authenticating a pre-identified set of documents," and that it was "unlikely to change course" absent "real and substantial prejudice." Appx1200.

The court then changed course. It refused to allow Mr. Marsh to authenticate the documents, on the ground that CH "failed to provide notice to Plaintiffs during discovery that Mr. Umesh Baheti ***would be authenticating MaxLite documents***." Appx355 (Oct. 27, 2021 Order) (emphasis added); *see* Appx1212 (25:21-28:4); Appx1213 (29:2-11). But the court identified no rule or order requiring parties to identify what documents each witness would authenticate, because there is none. The Federal Rules and local rules merely require pretrial disclosure of witnesses' names, addresses, and telephone numbers. *See* W.D. Tex. L.R. CV-16(f)(5); Fed. R. Civ. P. 26(a)(3). ***Super's*** pretrial disclosures ***also*** did not identify which witnesses would authenticate which documents. Appx21288-21325. Excluding CH's highly relevant evidence of invalidity based on a nonexistent disclosure requirement that Super did not follow—and consequently granting JMOL against CH—was legal error, an improper double standard, and an abuse of discretion.

<u>Substantial justification</u>. The district court also failed to address whether any failure of disclosure—and there was none—was "substantially justified," "harmless," or both. Fed. R. Civ. P. 37(c)(1). CH disclosed both the MaxLite documents as anticipated trial exhibits and Mr. Baheti as the MaxLite witness; Super had to know Mr. Baheti would be authenticating MaxLite documents. CH sought to use an alternate MaxLite witness (the previously disclosed "MaxLite Representative") only because the court rescheduled the trial to a date that conflicted with Mr. Baheti's

religious observance, rendering him unavailable. That is a substantial justification. The district court initially recognized that, and the absence of prejudice: It initially stated that, given Mr. Baheti's religious conflict, it did not "have an issue with" an alternative authenticating witness, and was "unlikely to change course" unless Super "show[ed] some real and substantial prejudice." Appx1200. But the court changed positions with no such showing.

The court never suggested that substituting one corporate representative would be anything but harmless: Mr. March merely would have authenticated business records timely identified as trial exhibits. *See Tex. A&M Research Found. v. Magna Transp., Inc.*, 338 F.3d 394, 402 (5th Cir. 2003) (any prejudice from late disclosure cured by giving opposing party adequate time to "examine and respond to the contested evidence"). Super's suggestion that it had no "opportunity to depose Mr. Marsh on [the MaxLite] documents," Appx1184, was makeweight—Super chose not to ask ***Mr. Baheti*** about the documents when it deposed him, *see* Appx1206-1207 (4:14-5:19).

There was likewise no justification for not accommodating Mr. Baheti's religious observance by letting him give authentication testimony at another time. Appx1207 (5:20-25); Appx1212 (25:16-20).[7] Congress has enacted the policy that

[7] Like other prerequisites to admissibility, "[t]he court must decide" authenticity and may do so without the jury's presence. Fed. R. Evid. 104(a), (c); *see* Fed. R. Civ. P. 16(c)(2)(C).

"[g]overnment shall not substantially burden a person's exercise of religion" absent "compelling" reasons. 42 U.S.C. § 2000bb-1(a), (b)(2). The right to participate in the judicial process as a witness merits similar respect.

Super's alternative arguments. Super offered two arguments the district court did not accept. Super objected that Mr. Baheti and Mr. Marsh lacked personal knowledge of the MaxLite documents. Appx21584-21585 & n.12. But " 'there is no requirement that the witness who lays the foundation' " for a business record " 'be able to personally attest to its accuracy.' " *United States v. Smith*, 804 F.3d 724, 729 (5th Cir. 2015); *CFTC v. Dizona*, 594 F.3d 408, 415 (5th Cir. 2010).

Super complained that CH identified a "MaxLite Representative" instead of Mr. Marsh specifically. But district courts in the Fifth Circuit and elsewhere agree that disclosing a " 'corporate representative[ ],' or something similar," suffices, *Jones v. RealPage, Inc.*, No. 3:19-CV-2087-B, 2020 WL 6149969, at *3 (N.D. Tex. Oct. 19, 2020) (collecting cases)—particularly where, as here, testimony is "corporate in nature and could have been elicited from a number of . . . executives," *Moore v. Computer Assocs. Int'l, Inc.*, 653 F. Supp. 2d 955, 959-60 (D. Ariz. 2009).

* * *

Lacking meaningful responses to much of the above, the district court denied a new trial by simply declaring—without explanation—that "Defendants' arguments [are] unpersuasive and not sufficient to warrant a new trial." Appx69. That brushoff fails to justify exclusion of indisputably relevant evidence—especially where the exclusion resulted in JMOL. Absent compelling grounds for refusing, the court should have accommodated Mr. Baheti's religious observance. Failing that, it should have allowed a substitute witness. Failing that, it should not have invoked, for one side only, a nonexistent rule requiring prior disclosure of who will authenticate documents. Failing that, it should have recognized the documents and the tubes were admissible regardless. Failing that, it should have hewed to the Federal Rules and precedent that expert testimony itself is sufficient evidence for a jury and that experts need not rest their opinions on admitted evidence.

The exclusion of highly relevant evidence exacts a heavy toll on the truth-finding function. Here, those cascading failures did not merely undermine the jury's ability to "ascertain[] the truth," Fed. R. Evid. 102—it resulted in the issue being taken away from the jury altogether.

3. *The District Court Erroneously Excluded Super's Internal Presentation*

The district court also excluded an internal Super presentation from August 2014, DX41 (Appx20068-20081), showing that Super had conducted an in-house teardown of Cree and Philips LED tube lamps from the same product lines Dr. Lebby examined. Appx10050(5:15-19); Appx10217(74:4-25, 75:1-6). The document reinforced Dr. Lebby's opinion that the tubes were prior art. It showed that Super possessed Cree and Philips tubes in August 2014, before the patents' priority date.

Because the tubes were made by Super's competitors, Super logically could possess them only if they were on sale or otherwise publicly available at that time. Appx10113-10114(23:6-25:14); 35 U.S.C. §102(a)(1).

Despite acknowledging that DX41 "may invalidate the patent," the district court excluded it as irrelevant, on the view that it "only deal[t] with inequitable conduct." Appx10050(5:15-19, 7:12-16). But the document was plainly relevant to invalidity. The "bar" for relevance is "low": "evidence is relevant if it has '***any*** tendency to make the existence of any fact that is of consequence to the determination of the action more probable or less probable than it would be without the evidence.'" *Hicks-Fields v. Harris County*, 860 F.3d 803, 809 (5th Cir. 2017) (emphasis added). DX41 cleared that bar: Super's possession of competitors' products in 2014 made it "more probable" that the products were publicly available in 2014 and thus prior art. DX41 spoke directly to the issue on which the court later granted JMOL. Such "competent evidence cannot be excluded without a sound and acceptable reason," *Davidson Oil Country Supply, Inc. v. Klockner, Inc.*, 908 F.2d 1238, 1245 (5th Cir.), *on reh'g*, 917 F.2d 185 (5th Cir. 1990)—particularly where, as here, the exclusion "struck at the heart of [CH's] case," *Murphy v. Magnolia Elec. Power Ass'n*, 639 F.2d 232, 235 (5th Cir. 1981).

Denying CH's new-trial motion, the district court embraced Super's protest that the tubes Super analyzed were slightly different models than those Dr. Lebby examined. Appx69-70. But the only difference Super identified was minor variation in wattage: The Philips tube Super tore down was "a 14 watt," while the "tube in Lebby's report for invalidity is a 16 and a half watt." Appx10114(27:25-28:3); *compare* Appx20071-20073, Appx20077-20079 *with* Appx21171. Super never argued the tubes differed in any way ***material to invalidity***. Dr. Lebby was prepared to testify that the models were indistinguishable for invalidity purposes, because wattage has no bearing on "the claims at issue." Appx10114(28:11-17). The trivial difference Super (and the district court) invoked thus hardly rendered DX41 ***irrelevant***: The document continued to make it more probable that products satisfying each claim limitation were publicly available before the priority date. Nothing more was required to clear relevance's "low" bar. *Hicks-Fields*, 860 F.3d at 809.[8]

C. This Court Should Hold the Patents Invalid

The district court's evidentiary errors clouded what should have been an easy issue: The asserted claims of the '125 and '540 patents are plainly anticipated or obvious. The parties' disputes concerned whether skilled artisans would have thought to glue established technology—LED strips and diffusion film—directly to lamp tubes. The prior-art lamp tubes the court excluded showed skilled artisans had already done so. Regardless, electrical engineers with three years' experience

[8] Super never attempted to show, and the district court never found, that DX41's probative value was "substantially outweighed" by "unfair prejudice" or any other ground for exclusion under Rule 403.

designing lighting fixtures, Appx10239(162:16-20), plainly would understand that they could affix LED strips or diffusion films directly to lamp tubes. Such "trivial improvements . . . would have been a matter of common sense," and "no reasonable jury could find [them] to have been nonobvious." *Western Union Co. v. MoneyGram Payment Sys., Inc.*, 626 F.3d 1361, 1372 (Fed. Cir. 2010).

The PTO has now rejected the '125 and '540 patents' asserted claims as obvious in *ex parte* reexaminations. Appx22047-22066; Appx22067-22106. Prior art specifically disclosed use of an "adhesive layer" to affix the LED strip to a lamp tube, a method "well-known at the [priority date] for securing the position of the LED assembly onto the inner surface." Appx22074. The evidence the district court wrongly excluded would have compelled—or at least allowed—a reasonable jury to likewise find the claims invalid. If this Court does not order judgment for CH, a new trial is required. *Jordan*, 977 F.3d at 417; *Davidson Oil*, 908 F.2d at 1245.[9]

II. SUPER'S VALIDITY THEORY REWRITES CLAIM 1 OF THE '140 PATENT AND WOULD PRECLUDE INFRINGEMENT IF ACCEPTED

Claim 1 of the '140 patent recites a shock-protection system that uses short pulses to test whether the lamp is properly installed and then activate or deactivate the switch controlling the main power circuit. Super attempted to distinguish Ono,

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[9] Because the jury "rendered a single verdict on damages, without breaking down the damages attributable to each patent," JMOL or a new trial for ***any*** claim "would require a new trial as to damages" for any remaining claims. *Verizon Servs. Corp. v. Vonage Holdings Corp.*, 503 F.3d 1295, 1310 (Fed. Cir. 2007).

a prior-art reference disclosing the same system, because it used a measure of impedance, rather than a pulse, to test installation before activating the main circuit. But Super then accused CH products with LT2600 chips even though they relied on the same detection of impedance.

Super cannot have it both ways. A "'patent may not, like a nose of wax, be twisted one way to avoid [invalidity] and another to find infringement.'" *Comm-Scope Techs. LLC v. Dali Wireless Inc.*, 10 F.4th 1289, 1299 (Fed. Cir. 2021).

A. Ono Anticipates Claim 1 of the '140 Patent

Prior art anticipates under § 102(a) when "every limitation is found either expressly or inherently in a single prior art reference." *Celeritas Techs., Ltd. v. Rockwell Int'l Corp.*, 150 F.3d 1354, 1361 (Fed. Cir. 1998). The parties did not dispute that Ono discloses most of claim 1's limitations: a pulse generating circuit, a switch circuit, an installation detection circuit that generates power only during proper installation, and a sampling signal that identifies whether the lamp is properly installed. *See* pp. 17-18, *supra*.

Ono also clearly discloses the single limitation Super contested: "pulse signals [that] control turning on and off of the switch circuit." Appx189 (59:6-7); Appx10221 (90:15-92:13). Ono discloses a "signal output circuit" that "outputs a voltage signal" such as a "rectangular pulse"—*i.e.*, a pulse signal. Appx10014 (¶47). That pulse signal then controls the switch circuit: A "first determination circuit" performs a "determination process on the basis of the voltage detected," and the result of that determination process acts as a "signal for switching the switch" from "the ON state to the OFF state" if the lamp is not properly installed. Appx10013-10017(¶¶42, 44, 61).

Confronted by that clear disclosure, Super sought to rewrite both Ono and claim 1. Super's expert, Dr. Phinney, testified that Ono practiced the "old way with respect to shock protection," because it "first check[s]" whether "installation is proper" and ***then*** turns on the switch that activates the light. Appx10221(90:13-24, 91:20-22). According to Dr. Phinney, claim 1 instead "goes right ahead and turns on the light first and ***then*** determines if there's a proper installation." Appx10221(90:23-91:5) (emphasis added). Dr. Phinney also urged that Ono controlled the switch not with pulses of voltage (*i.e.*, pulse signals), but with a "detection" of "impedance," which was a "response" to the pulse signal that the system obtained before activating the switch. Appx10221(91:6-19).

Dr. Phinney's testimony contradicts Ono and the '140 patent. Ono does not mandate detecting proper installation ***before*** switching the light on. It discloses switching "from the ON to the OFF state . . . when, in the first determination process, it has been determined that there is an open state," *i.e.*, improper installation. Appx10013(¶42). In other words, Ono can first activate the main circuit—switch it to "ON"—and later switch it "OFF" if it determines the light is not properly installed.

Nor does claim 1 of the ’140 patent mandate any specific order of operations, much less the one Dr. Phinney urged. Upon detecting that “the LED tube lamp is not properly installed,” the installation detection circuit can control “the switch circuit to ***remain*** in an off state.” Appx189(59:11-14) (emphasis added). That language contradicts Dr. Phinney’s suggestion that the invention necessarily “turns on the light first” and only then determines whether installation is proper or improper. Appx10221(90:23-91:5). The switch cannot “***remain*** in an ***off*** state” upon detecting improper installation if it is already in an ***on*** state. Claim 1 thus encompasses a system that turns on the light only ***after*** detecting proper installation—precisely what Dr. Phinney described as the “old way” disclosed in Ono. Appx10221(90:13-91:22).

Claim 1 also cannot be distinguished from Ono on the ground that Ono detects impedance. Claim 1 recites an “installation detection circuit” that detects “during at least one of the one or more pulse signals whether the LED tube lamp is properly installed.” Appx188-189(58:66-59:4). That language contemplates that pulses will produce a detection “response” that identifies whether installation is proper. Appx10221(91:6-19). Claim 1 does not preclude that response from being a measure of impedance. As Super argued regarding infringement, claim 1 “say[s] nothing about what electrical property needs to be measured.” Appx21611. It thus encompasses an “installation detection circuit” that uses a measure of impedance to determine "whether the LED tube lamp is properly installed," Appx188-189 (58:66-59:4)—precisely what Dr. Phinney described Ono as reciting, Appx10221 (91:6-19).

CH raised the contradiction between Dr. Phinney's testimony and claim 1's plain language, Appx20018-20020, but the district court never addressed it. It responded that the jury was "free" to "adopt Dr. Phinney's description of Ono over Dr. Zane's." Appx57. But Dr. Phinney was not free "to vary or contradict the claim language" by attributing to the '140 patent an order of operations that claim 1 refuted. *Vitronics Corp. v. Conceptronic, Inc.*, 90 F.3d 1576, 1584 (Fed. Cir. 1996); *see Phillips v. AWH Corp.*, 415 F.3d 1303, 1318 (Fed. Cir. 2005) ("[A] court should discount any expert testimony 'that is clearly at odds with the claim construction mandated by the claims themselves . . . .' "). Without varying claim 1's language, Dr. Phinney had no basis for distinguishing Ono. JMOL on claim 1 is warranted. A damages retrial is required on all other claims. *See* p. 47, n.9, *supra*.

B. Alternatively, Products with LT2600 Chips Do Not Infringe

Having distinguished Ono as disclosing an impedance-based shock-prevention system to avoid invalidity, Super could not accuse other impedance-based systems of infringement. But Super did precisely that for CH products with LT2600 chips, which practice a "grid ***impedance*** measured algorithm." Appx10034 (emphasis added). Super cannot have it both ways. If its evidence sufficed to avoid judgment of invalidity, then it required judgment of non-infringement for LT2600-chipped lamps.

Each asserted claim of the ’140 patent requires using “pulse signals” to turn the switch circuit on and off. Appx188-189 (58:61-59:32, 60:9-55), Appx191-192 (64:23-44, 65:9-11, 65:25-31). Dr. Phinney distinguished Ono on the ground that Ono used detections of “***impedance***,” rather than pulses of ***voltage***, to control the switch circuit. Appx10221 (91:6-19); *see* pp. 18-19, *supra*. But the LT2600 chips undisputedly use impedance: They employ a “grid ***impedance*** measured algorithm” to control the switch circuit in the accused products. Appx10034 (emphasis added). They detect “two signals, voltage and current,” and compare the “combination” of these two signals—*i.e.*, impedance—against a “threshold” measurement. Appx10166-10167 (236:1-238:7). That is the same kind of impedance-based “detection” result that Dr. Phinney ***distinguished*** when characterizing Ono as detecting a “response” to the “pulse,” rather than the pulse itself. Appx10221 (91:6-19); *see* Appx188-189 (58:61-59:32). Super’s infringement expert, Dr. D’Andrade, agreed that the LT2600 chips use that response to control the lamp’s power switch. Appx10095 (186:21-187:6).[10]

[10] Dr. D’Andrade also confirmed that LT2600 chips could practice the order of operations Dr. Phinney described as the “old way,” ***first*** detecting proper installation and ***then*** turning on the light: “[I]t’s making a determination, is someone touching, ***stay off***. If no one is touching, it’s properly installed, ***turn on***.” Appx10095 (186:21-187:6) (emphasis added).

The district court never addressed Super's inconsistent positions on invalidity and infringement, *see* Appx60, even though CH moved for JMOL on that basis, Appx20018-20020. Nor did Super resolve the contradiction. It argued only that claim 1 "say[s] nothing about what electrical property needs to be measured," Appx21610-21611, contradicting its expert's testimony that measuring ***impedance*** does not practice the patented invention, Appx10221(91:6-19) (Phinney). Having chosen to distinguish prior art based on its detection of impedance, rather than pulses of voltage, to control the switch circuit, Super could not accuse the LT2600 chips' impedance-based system of infringing. *CommScope*, 10 F.4th at 1299. If Ono's impedance-based shock-prevention system does not anticipate, then the LT2600 chips' impedance-based shock-prevention system does not infringe any claim of the '140 patent.

CommScope underscores the error. When addressing invalidity, the plaintiff there argued that claim language required a circuit controller to place itself "'in a non-operating state.'" 10 F.4th at 1299. But for infringement, the plaintiff contended that the same controller ***could not*** be "turned 'off.'" *Id.* This Court rejected the "apparent" "incongruity" in patentee's arguments and ordered judgment of non-infringement. *Id.* It should do the same here.

III. SUPER'S ERRONEOUS DAMAGES METHODOLOGY REQUIRES REVERSAL

To "be admissible, all expert damages opinions must separate the value of the allegedly infringing features from the value of all other features." *Commonwealth Sci. & Indus. Rsch. Org. v. Cisco Sys., Inc.*, 809 F.3d 1295, 1301 (Fed. Cir. 2015). Super's damages expert, Ms. Kindler, thus was required to determine the value of the alleged inventions themselves—affixing an LED strip or diffusion film directly to a lamp tube, as in the '125 and '540 patents, and the putatively different shock-protection system recited in the '140 patent. She did not. Instead, she proposed—and the jury adopted—a ***greater*** royalty for any ***one*** of the asserted patents than Super ever received for its ***entire 260-patent portfolio***.

A. Super Failed To Apportion

This Court has repeatedly emphasized the need to account for differences between comparable licenses—especially portfolio licenses—and the hypothetical negotiation, to ensure damages are apportioned to reflect the value of the specific patents at issue. *Apple Inc. v. Wi-LAN Inc.*, 25 F.4th 960, 973-74 (Fed. Cir. 2022); *Omega Patents, LLC v. CalAmp Corp.*, 13 F.4th 1361, 1381 (Fed. Cir. 2021); *MLC Intell. Prop., LLC v. Micron Tech., Inc.*, 10 F.4th 1358, 1373 (Fed. Cir. 2021); *Adasa Inc. v. Avery Dennison Corp.*, 55 F.4th 900, 915 (Fed. Cir. 2022). Ms. Kindler's proposed royalty of $0.30-$0.45/unit, Appx10126-10127 (76:24-77:8)—purportedly derived from Super's portfolio licenses with TCP and Lunera, Appx10120(52:16-20)—violates that requirement in four different ways.

1. *Ms. Kindler Failed To Account for Differences Between Super's Portfolio Licenses and the Hypothetical Negotiation*

Damages experts must account for differences between portfolio licenses and hypothetical negotiations over the patents-in-suit. *Wi-LAN*, 25 F.4th at 972-73; *Omega*, 13 F.4th at 1380-81; *MLC*, 10 F.4th at 1375. A mere assertion that certain patents "dr[o]ve the royalty rate for a license, and the rest of the portfolio [was] included for a marginal upcharge," is insufficient. *Wi-LAN*, 25 F.4th at 972. In *Wi-LAN*, an expert testified that two patents-in-suit were "key" to a portfolio license. *Id.* But his basis for that assertion—that one patent was discussed during negotiations and listed in the license as "Asserted"—applied equally to "five other" patents ***not*** at issue in the suit. *Id.* at 973. The expert's "silence on these equally situated patents" made his opinion "unreliable" and required a new trial. *Id.* at 973-74.

Ms. Kindler's opinions were ***less*** reliable than the opinions held inadmissible in *Wi-LAN*. She purported to apply the TCP license's $0.30/unit portfolio royalty—or increase it to $0.45/unit—because "a subset of patents," including the '140 patent, supposedly "drove" the "negotiation" and "final terms" of the TCP license. Appx10121(54:10-25). But the document she invoked listed the '140 patent among

thirteen other patents that were ***not*** asserted here. Appx21732.[11] While Ms. Kindler testified that some patents were "similar" to the '125 and '540 patents, she conceded she was not a technical expert, had not examined the patents, and simply "took [Super personnel's] word for it." Appx10121(54:3-17); Appx10129(86:22-87:4). Super presented ***no*** evidence from a competent witness about purported similarities between the '125 and '540 patents and those listed in the TCP license document. *See Wi-LAN*, 25 F.4th at 972-73 (rejecting expert's reliance on patent owner's description of patent "value" where evidence did not support it). Nor did Ms. Kindler address the value of other listed patents—much less explain why they should be treated as having zero or negative value. Her "silence on these equally situated patents" makes her testimony "unreliable." *Wi-LAN*, 25 F.4th at 973-74; *see Adasa*, 55 F.4th at 915 (excluding expert who "did not undertake any meaningful comparison of the licensed technology with the invention"); *MLC*, 10 F.4th at 1375 (expert must compare "licensed technology versus the accused technology to account for any differences").

Ms. Kindler's analysis of the Lunera license fares worse still. Super entered into that license in 2016, before any patent-in-suit issued. The patents-in-suit ***could***

[11] That document, like Dr. Lebby's supporting material, was not admitted into evidence. *See* p. 22, *supra*. Unlike Dr. Lebby's supporting material, however, there was no showing or finding that experts in the field would "reasonably rely on" this "kind" of document. Fed. R. Evid. 703.

not have driven Super's negotiations with Lunera. In fact, the license's two-year term (2016-2018) meant it never even covered the '125 and '540 patents, which issued in 2019. Appx21336; Appx193; Appx292. Ms. Kindler nonetheless testified that she discussed the asserted patents "at length with Super Lighting personnel," who asserted they were "very important patents to Super Lighting's portfolio" and "convey a lot of significant benefits" to Lunera. Appx10122-10123 (60:21-61:9). But patents that did not exist at the time of the license cannot be "very important" to that license. Ms. Kindler's testimony was "untethered to the facts of this case." *Wi-LAN*, 25 F.4th at 973-74. In any event, Ms. Kindler still needed to exclude the value of other "licensed technology" not at issue in this suit. *MLC*, 10 F.4th at 1375; *see Adasa*, 55 F.4th at 915. She did not, providing "no basis upon which to conclude" that the 260-patent Lunera license was "a meaningful proxy for the royalty rate of the" three patents-in-suit, *Wi-LAN*, 25 F.4th at 973—much less that it supported a ***greater*** royalty.

2. *Ms. Kindler Proposed a Greater Royalty for Three Patents Than Super Received for Its Entire Portfolio*

Ms. Kindler did not merely tell the jury to use the royalty rates from ***260***-patent portfolio licenses for the ***three*** patents here. She ***inflated*** those rates.

The TCP license included a portfolio royalty of $0.30/unit. Appx10123 (61:15-20). But Ms. Kindler proposed, and the jury adopted, a top-end royalty of $0.45/unit, forcing CH to pay ***more*** for any ***one*** of the three patents-in-suit than TCP paid for ***fourteen*** supposedly key patents and ***250*** others. Appx10132 (97:3-98:2); Appx10194 (346:9-347:19). That testimony is particularly egregious for the '125 and '540 patents. Those patents were ***not*** included in the "subset" of patents that allegedly "drove" the TCP license. Appx10121 (54:10-25); Appx21732. Under Ms. Kindler's own analysis, those patents were "chaff, not wheat," and thus worth ***less*** than any of the fourteen "key" patents. *Wi-LAN*, 25 F.4th at 973. But Ms. Kindler proposed that CH should pay ***more*** than the portfolio rate for the '125 and '540 patents—50% more for two bits of "chaff" than TCP paid for the whole bundle of "wheat." Such testimony is even less reliable than that held inadmissible in *Wi-LAN*, which ***discounted*** the portfolio rate by 25% to account for the additional patents it covered. 25 F.4th at 973.

The Lunera license fares worse. That license, entered in 2016, provided for a 5% portfolio royalty on the price "collected by Lunera," a ***wholesaler***. Appx21329; Appx10122 (57:22-59:16); Appx10193-10194 (344:6-346:6); Appx10130 (89:4-6). To calculate a per-unit royalty for CH, however, Ms. Kindler applied Lunera's 5% wholesale royalty to ***retail*** prices she found online in 2021. Appx10129-10130 (87:6-90:4). Because retail prices are significantly higher than wholesale, Ms. Kindler's calculation resulted in a ***10.8% to 13.9%*** royalty on CH's contemporaneous ***wholesale*** prices—for ***three*** patents. Appx10132 (97:17-98:2). Ms. Kindler offered no evidence that Super had ever collected such exorbitant royalties. She asserted that wholesale price declines since 2016 roughly offset the "retail mark-up." Appx10122 (59:17-60:19). But she never offered—at trial, in her expert report, anywhere—support for that assertion, much less reason why a 5% wholesale royalty for 260 patents justified a 13.8% wholesale royalty for three (or fewer) patents.

3. *Ms. Kindler's Conclusory Analysis Failed To Account for Purported Differences*

Ms. Kindler made no explicit adjustment for the vastly different numbers of patents—260+ in the other licenses, one to three here. Instead, she purported to identify ***additional*** differences that were allegedly "counterbalancing." Appx10121-10122 (55:12-57:21). She tried to justify inflating TCP's $0.30/unit portfolio rate to $0.45/unit because (1) CH was a "direct competitor," Appx10122 (57:8-21), and (2) "LED tube lamp prices have declined significantly," supposedly due to CH's "malicious pricing," between the hypothetical negotiation and the TCP license, Appx10121 (55:18-56:13).

But Ms. Kindler had to "'***account***'" for differences, including her supposed counterbalancing differences, not "merely ***identif[y]***" them. *Omega*, 13 F.4th at 1381 (emphasis added). She made no effort to quantify the impact of any difference. She did not explain how the differences in licensed technology—260+ patents, including fourteen supposedly key ones, versus three here—should affect the royalty rate. *MLC*, 10 F.4th at 1375. Nor did she explain how her "counterbalancing differences" would (conveniently) more than offset those differences. Such "generic" testimony that differences exist gives the jury no "basis in fact" to understand how those differences should impact damages. *Omega*, 13 F.4th at 1381.

Ms. Kindler's supposed differences, moreover, were untethered from the record. TCP was also Super's competitor. Appx10129(85:10-13). Far from "malicious," CH's average price was ***higher*** than Super's, Appx10131(95:20-96:14), and the district court rejected Super's argument that any price declines resulted from alleged infringement, Appx34-37. Contrary to Ms. Kindler's unsupported assertion, the district court found ***no evidence*** that Super suffered lost sales or profits from CH's alleged infringement. Appx40-42.

4. *Ms. Kindler Proposed the Same Royalty for Vastly Different Technologies*

Ms. Kindler further defied this Court's precedent by applying the same royalty regardless of which patent(s) a product infringed. Appx10126(73:11-75:23); *see* p. 21, n.3, *supra*. The patents claim vastly different technologies: The '125 and '540 patents address placement of LED strips and diffusion film, while the '140 patent recites a shock-protection system. Yet Ms. Kindler treated all those technologies as having the exact same value. Indeed, her royalty calculation remained unchanged from her initial report, which considered five additional patents that were eventually dropped. Appx10128(82:12-84:14). This Court has rejected such a mechanistic flat-rate approach.

In *Omega*, the patentee presented testimony that "the licensing fee was 'five dollars per unit whether it's one patent or 50 patents'"; that "no particular patent is treated as more valuable than another"; and that the policy was "'one price for all.'" 13 F.4th at 1379. This Court rejected that theory because it "would improperly permit [patentee] to hide behind its generic licensing arrangement to avoid the task of apportionment." *Id.* Likewise here, Ms. Kindler could not apply the "same licensing fee *regardless* of what patents were included or what technology was covered," particularly given the significant differences between the claimed technologies. *Id.*

B. The District Court Abused Its Discretion

The district court failed to address, much less excuse, those fatal deficiencies in Ms. Kindler's testimony. Although CH directed the district court's attention to this Court's decisions in *MLC* and *Omega*, Appx20042-20047, the district court never mentioned them, Appx70-76. It never considered Ms. Kindler's failure to assess "the licensed technology versus the accused technology to account for any differences," *MLC*, 10 F.4th at 1375; her lack of "'a basis in fact to associate'" the TCP and Lunera royalty rates with CH's hypothetical negotiation, *Omega*, 13 F.4th at 1381; or her impermissible "one price for all" approach, *id.* at 1379. Super never addressed those deficiencies either. Appx21588-21590; Appx21736-21740.

The district court failed to address *Omega* and *MLC* because Super did not. The court copied its opinion nearly ***verbatim*** from Super's supplemental brief on

Wi-LAN. *Compare* Appx73-76 *with* Appx21736-21740; *see* pp. 23-24, *supra*. Super having ignored *Omega* and *MLC*, so did the district court.

The effort to distinguish *Wi-LAN* is also unpersuasive. Super and the district court characterized *Wi-LAN* as "essentially a dispute about which licenses should be considered in the first instance, ***not*** how to apply relevant, agreed-upon licenses." Appx73 (emphasis added). That describes ***the defendant's arguments*** in *Wi-LAN*, not ***this Court's holding***—as made clear by Super's repeated citations to the *Wi-LAN* briefs, which outnumbered citations to the decision itself. Appx21736-21737 (citing *Wi-LAN* briefs (Ex. A, Dkt. 321-2; Ex. C, Dkt. 321-4) 15 times and *Wi-LAN* decision 8 times).

This Court's decision in *Wi-LAN* took ***as a given*** that the licenses at issue were sufficiently "comparable" to satisfy the "threshold requirement for licenses to be admissible." 25 F.4th at 971-72 & n.5. The Court held the expert's testimony inadmissible based ***not*** on his "consider[ing] them in the first instance," but on how he "appl[ied] relevant" comparable licenses, Appx73—*i.e.*, his "methodological and factual errors in analyzing the[m]," *Wi-LAN*, 25 F.4th at 974. It was the expert's failure to "***adjust*** for the differences" between those licenses and the hypothetical negotiation—not consideration of the licenses in the first place—that rendered his testimony "untethered to the facts." *Id.* at 972-73 (emphasis added).

Ms. Kindler made the same "methodological and factual errors"—indeed, she compounded them. Like the expert in *Wi-LAN*, Ms. Kindler testified that the patents that "drove" the TCP "negotiation" "included" not just the '140 patent, but also thirteen nonasserted patents. Appx10121 (54:10-25); Appx21732. But unlike in *Wi-LAN*, Ms. Kindler did not "discount" TCP's portfolio rate for the absence of those "key" patents. 25 F.4th at 973. She treated the portfolio rate as a ***floor***, opining that ***any one*** patent-in-suit—including two that were ***not*** "key" to the TCP license—was worth 50% ***more*** per-unit than Super's entire portfolio. *See* pp. 57-59, *supra*. That "makes [her] opinion unreliable." *Wi-LAN*, 25 F.4th at 973-74.

The district court's observation that CH's expert also considered the TCP and Lunera licenses, Appx75, repeats the erroneous effort to distinguish *Wi-LAN*. CH did not "'challenge the comparability of its own comparable.'" *Versata Software, Inc. v. SAP Am., Inc.*, 717 F.3d 1255, 1268 (Fed. Cir. 2013). CH's expert "disagree[d] with ***the way Ms. Kindler uses*** [the TCP and Lunera] agreements from an economic standpoint." Appx10205 (28:17-21) (emphasis added). Those "methodological and factual errors in analyzing" the licenses, not lack of comparability, render her testimony unreliable. *Wi-LAN*, 25 F.4th at 974.

The district court's suggestion that errors in Ms. Kindler's comparable-license analysis were not "prejudicial" because she also discussed *Georgia-Pacific* "factors 5, 8, 11, and 13," Appx76 (citing Appx10120 (49:13-50:11)), is unfounded. Super's portfolio licenses were the centerpiece of Ms. Kindler's testimony. They were the ***only*** basis she provided for the specific royalty rates she proposed ($0.30-$0.45/unit) and the jury adopted ($0.45/unit), and occupied more of her testimony than all other factors combined. Appx10120-10123 (51:1-62:9) (comparable-license analysis); Appx10123-10125 (62:10-69:10) (other *Georgia-Pacific* factors). Even if her (cursory) discussion of other "factors" were unobjectionable, it "cannot overcome the substantial infirmities" with her comparable-license analysis—without that faulty analysis, she would have ***no*** rate to propose at all. *Lucent Techs., Inc. v. Gateway, Inc.*, 580 F.3d 1301, 1335 (Fed. Cir. 2009).

Ms. Kindler's discussion of other *Georgia-Pacific* factors was flawed regardless. She opined that supposed "benefits of the patents-in-suit" and "demand[] in the marketplace" would (to some unspecified degree) "place upward pressure on" a negotiated royalty. Appx10124 (66:7-68:2). But the district court recognized there was no "evidence showing that customers care about shock protection *particular to the patented features*" or that "the patented feature 'impacts customers' purchasing decisions.'" Appx40-42. Ms. Kindler also invoked "competition between the parties" and lost "sales and profits." Appx10123-10124 (62:11-12, 65:9-12). But the court found no evidence that Super lost sales or profits to CH's ***use of the patented technology***, as opposed to "lawful competition." Appx37. The court never reconciled its acceptance of Ms. Kindler's testimony with its rejection of her factual premises.

The district court (and Super) fare no better in asserting that "a new trial motion is an improper vehicle" for raising allegedly unpreserved objections to Ms. Kindler's testimony. Appx70-71; Appx21588. CH filed a *Daubert* motion challenging Ms. Kindler's analysis of the TCP and Lunera licenses, Appx1094-1099, which the district court denied, Appx1119(27:15-16). That alone preserved CH's challenge: Under Rule 103, "'[o]nce the court makes a definitive ruling on the record[,] . . . *either at or before trial*, a party need not renew an objection . . . to preserve a claim of error for appeal.'" *Micro Chem., Inc. v. Lextron, Inc.*, 317 F.3d 1387, 1391 (Fed. Cir. 2003) (Fifth Circuit law).

Regardless, failure to object at trial could "not act as waiver as to a challenge to the sufficiency of the evidence for the jury to award damages." *Omega*, 13 F.4th at 1379 n.10. In *Omega*, this Court ordered a new trial based on the insufficiency of the plaintiff's damages evidence, as Rule 50(b)(2) specifically contemplates. *Id.* at 1377. Nor does *i4i Limited Partnership v. Microsoft Corp.*, 598 F.3d 831 (Fed. Cir. 2010) (cited Appx71), support waiver. The defendant there "fail[ed] to file a pre-verdict JMOL on damages." *Id.* at 845. Here, CH ***twice*** moved for JMOL on the insufficiency of Ms. Kindler's testimony, challenging her analysis of both the TCP and Lunera licenses. Appx10133(101:12-102:4); Appx10216(70:12-71:9). Those motions, too, amply preserved the arguments. *Omega*, 13 F.4th at 1379 n.10.

The district court's verbatim copying of Super's supplemental brief underscores its departure from this Court's apportionment precedent. The Supreme Court has "criticized" the "verbatim adoption of findings of fact prepared by prevailing parties," a rationale that applies *a fortiori* to copying their briefs. *Jefferson v. Upton*, 560 U.S. 284, 293-94 (2010). There "is no authority in the federal courts that countenances the preparation of the opinion by the attorney for either side." *Chicopee Mfg. Corp. v. Kendall Co.*, 288 F.2d 719, 724-25 (4th Cir. 1961). "That practice involves the failure of the trial judge to perform his judicial function." *Id.* The district court's uncritical adoption of briefing that failed to address binding precedent like *MLC* and *Omega*—cases CH discussed extensively—undermines the "appearance of justice" and warrants reassignment on remand. *Miller v. Sam Houston State Univ.*, 986 F.3d 880, 892-93 (5th Cir. 2021); *Int'l Rectifier Corp. v. Samsung Elecs. Co.*, 238 F. App'x 601, 604 (Fed. Cir. 2007).

CONCLUSION

The district court's judgment should be reversed.

July 25, 2023

Respectfully submitted,

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ADDENDUM

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**IN THE UNITED STATES DISTRICT COURT
FOR THE WESTERN DISTRICT OF TEXAS
WACO DIVISION**

JIAXING SUPER LIGHTING ELECTRIC APPLIANCE CO., LTD. AND OBERT, INC., Plaintiffs, v. CH LIGHTING TECHNOLOGY CO., LTD., ELLIOTT ELECTRIC SUPPLY INC. AND SHAOXING RUISING LIGHTING CO., LTD., Defendants.	§ § § § § § § § § § § §	CASE NO. 6:20-CV-00018-ADA JURY TRIAL DEMANDED

<u>ORDER OF JUDGMENT</u>

In accordance with the Court's July 21, 2022 Order (ECF No. 281) and the jury's verdict in this case (ECF No. 230), the Court ORDERS, ADJUDGES, and DECREES that a judgment is hereby granted in favor of Plaintiffs Jiaxing Super Lighting Electric Appliance Co., Ltd. and Obert, Inc. (collectively, "Super Lighting") and against Defendants CH Lighting Technology Co., Ltd. and Shaoxing Ruising Lighting Co., Ltd. (collectively, "CH") and Defendant Elliott Electric Supply Inc. ("Elliott"), as follows:

IT IS ORDERED that judgment be and is hereby entered in favor of Super Lighting against CH and Elliott with respect to the infringement of claims 1, 4, 5, 24, 28 and 31 of U.S. Patent No. 9,939,140 (the "'140 patent"), claims 13 and 14 of U.S. Patent No. 10,352,540 (the "'540 patent"), and claim 1 of U.S. Patent No. 10,295,125 (the "'125 patent");

IT IS FURTHER ORDERED that judgment be and is hereby entered in favor of Super Lighting against CH and Elliott that claims 1, 4, 5, 24, 28 and 31 of the '140 patent, claims 13 and 14 of the '540 patent, and claim 1 of the '125 patent are not proved invalid;

IT IS FURTHER ORDERED that judgment be and is hereby entered in favor of Super Lighting against CH that CH's infringement was willful;

IT IS FURTHER ORDERED that judgment be and is hereby entered in favor of Super Lighting against CH for damages in the amount of $21,214,708, an amount that is the sum of:

(1) the jury's verdict in an amount of $13,872,872;

(2) $7,155,432 in enhanced damages, reflecting an award of $0.45 per unit for all infringing products sold between the date CH learned of the '140 patent, February 16, 2019, and the date when CH filed its answer, December 3, 2020; and

(3) prejudgment interest in an amount of $186,404.

IT IS FURTHER ORDERED that post judgment interest shall accrue on the damages awarded against CH in accordance with 28 U.S.C. § 1961.

IT IS FURTHER ORDERED that judgment be and is hereby entered in favor Super Lighting against Elliott for damages in the amount of $302,365, an amount that is the sum of:

(1) the jury's verdict in an amount of $298,454; and

(2) prejudgment interest in an amount of $3,911.

IT IS FURTHER ORDERED that post judgment interest shall accrue on the damages awarded against Elliott in accordance with 28 U.S.C. § 1961.

The Court hereby ORDERS CH and Elliott to pay Super Lighting the amounts detailed above.

IT IS FURTHER ORDERED that Defendants CH and Elliott pay Super Lighting $147,420.61 as jointly agreed by the Parties and laid out in their Agreed Bill of Costs (ECF No. 278-1).

The Court DENIES all relief not granted in this judgment.

SIGNED this 29th day of July, 2022.

ALAN D ALBRIGHT
UNITED STATES DISTRICT JUDGE

IN THE UNITED STATES DISTRICT COURT
FOR THE WESTERN DISTRICT OF TEXAS
WACO DIVISION

JIAXING SUPER LIGHTING ELECTRIC APPLIANCE CO., LTD. and OBERT, INC., **Plaintiffs,** ***v.*** **CH LIGHTING TECHNOLOGY CO., LTD., ELLIOTT ELECTRIC SUPPLY INC., and SHAOXING RUISING LIGHTING CO., LTD.,** **Defendants.**	**6:20-cv-00018-ADA**

[AMENDED] MEMORANDUM OPINION & ORDER

Came on for consideration this date are Plaintiffs' Motion for Enhancement of Damages Under 35 U.S.C. § 284, ECF No. 233; Plaintiffs' Motion for Permanent Injunction, ECF No. 234; Plaintiffs' Opposed Motion for Exceptional Case and Attorney Fees, ECF No. 241; and Plaintiffs' Motion for Entry of Judgment, ECF No. 242.[1]

I. BACKGROUND

On January 10, 2020, Plaintiffs Jiaxing Super Lighting Electric Appliance Co., Ltd. ("Super Lighting") and Obert, Inc. ("Obert") (collectively, "Plaintiffs") initiated this Action by filing a complaint alleging that Defendants CH Lighting Technology Co., Ltd. ("CH Lighting" or "CH"), Elliott Electric Supply Inc. ("Elliott"), and Shaoxing Ruising Lighting Co. Ltd. ("Ruising")

[1] The Court issued a sealed opinion on these motions on July 21, 2022. ECF No. 281. It then issued a public version of that sealed opinion on August 2, 2022. ECF No. 285. This amended order corrects typographical errors, including one instance in which the Court erroneously mixed up the parties. This amended order **SUPERSEDES** its earlier opinions at ECF Nos. 281 and 285 but should not be read to affect the final judgment at ECF No. 284 or any deadlines running from the date of its issuance.

(collectively, "Defendants") infringe certain U.S. patents. ECF No. 1 (the "Complaint"). On March 16, 2020, Plaintiffs filed an amended complaint alleging infringement of U.S. Patent Nos. 10,295,125 (the "'125 patent"), 10,342,078, 10,352,540 (the "'540 patent"), and 10,426,003, 9,939,140 (the "'140 patent"), 10,378,700, 10,448,479, and 10,560,989. ECF No. 21 (the "FAC"). CH answered on December 3, 2020. ECF No. 67. The Plaintiffs' patents and Defendants' accused products are directed to light-emitting diode (LED) tube lamps and features thereof.

Super Lighting is a Chinese corporation and Obert is its North American affiliate. ECF No. 21 ¶¶ 1, 2. CH and Ruising are also Chinese corporations and Elliott is a customer of some sort based out of Texas. *See, e.g.*, ECF No. 237 at 40:12–20, 46:18–22, 78:9–79:10. Ruising is the subsidiary of CH charged with selling CH products.[2] *See id.* at 78:9–79:10. Super Lighting and CH are rivals in the tube lamp space. Ruising is owned at least by Caiying Gan, CEO of CH, and Qingbo "Jack" Jiang, who also runs Ruising. *See id.* at 78:9–79:10. Before he was at Ruising, Jack Jiang was a Super Lighting employee. He left in 2014 to join Ruising and later convinced Jun Yang, technical assistant and secretary to Super Lighting's CEO and founder, to join him there. *See id.* at 82:15–83:7. According to Super Lighting's CEO, Mr. Yang had access to Super Lighting's most confidential, technical documents. *Id.* at 82:24–83:5. Mr. Yang is now a product manager at Ruising. *See id.* at 204:1–9.

On October 6, 2021, the Court held a pre-trial conference in this Action. *See* ECF Nos. 190, 191. Trial commenced on November 1, 2021. *See* ECF No. 216. At trial, Plaintiffs had narrowed their case such that they only asserted infringement of claim 1 of the '125 patent, claims

[2] When the Court refers to CH it is oftentimes referring to CH and Ruising collectively.

1, 4, 5, 24, 28, and 31 of the ’140 patent, and claims 13 and 14 of the ’540 patent. Shortly before trial, Defendants stipulated that:

> all existing versions of all products accused of infringing the ’540 Patent infringe claims 13 and 14 of the ’540 Patent, including the following products: CH1118 series, CH1128 series, CH1152 series, CH11152S series, CH1152-42W-FA8 series, CH1152AS series, CH1152SD series, CH1155C series, CH1156 series, CH1157 series, CH1157S series, CH1157AS series, CH1157SD series, CH1180 series, CH1198 series, CH1198D series, LV1118, LV1153DA, LV1155, LV1155NA, LV1156, ESL Vision GDT series, ESL Vision PBC series, GE Current BDT series (*e.g.,* LED14BDT8/G4/840). The infringing products include products within the foregoing series manufactured by CH Lighting and Ruising for sale under different brand names; for example, the “CH1152S series” includes the Keystone-branded KT-LED7T8-24GC-840-DX2, others in that series, the Maxlite-branded L11.5T8DE440-CG4, and others in that series.

Id. at 8. Defendants further stipulated:

> that all existing versions of all products accused of infringing the ’125 Patent infringe claim 1 of the ’125 Patent, including the following product series: CH1118 series, CH1128 series, CH11152S series, CH1152-42W-FA8 series, CH1152AS series, CH1152SD series, CH1155C series, CH1156 series, CH1157S series, CH1157AS series, CH1157SD series, CH1180 series, CH1180AX series, CH1198 series, CH1198D series, LV1118, LV1153DA, LV1155, LV1155NA, LV1156, ESL Vision GDT series, ESL Vision PBC series, GE Current BDT series (e.g. LED14BDT8/G4/840). The infringing products include products within the foregoing series manufactured by CH Lighting and Ruising for sale under different brand names; for example, the “CH1152S series” includes the Keystone-branded KT-LED7T8-24GC-840-DX2, others in that series, the Maxlite-branded L11.5T8DE440-CG4, and others in that series.

Id. at 8–9. Moreover, Defendants stipulated:

> that the following products accused of infringing the ’140 patent infringe claims 1, 4, 5, 24, 28, and 31 of the ’140 Patent: CH11152S series, CH1152-42W-FA8 series, CH1152AS series, CH1157S series, CH1157AS series, CH1152SD series, CH1157SD series, CH1198D, ESL Vision GDT series, ESL Vision PBC series, GE Current BDT series (*e.g.,* LED14BDT8/G4/840). This excludes such products sold with the LT2600 integrated circuit, which remain

> disputed. The infringing products include products within the foregoing series manufactured by CH Lighting and Ruising for sale under different brand names; for example, the "CH1152S series" includes the Keystone-branded KT-LED7T8-24GC-840-DX2, others in that series, the Maxlite-branded L11.5T8DE440-CG4, and others in that series.

Id. at 9. Altogether, Defendants stipulated to infringement for all but one accused product—Defendants argued to the Jury that the LT2600 integrated circuit did not infringe the asserted claims of the '140 patent. Defendants also presented an invalidity case against the '125, '140, and '540 patents (the "Asserted Patents") to the Jury.

On the third day of trial, the Court granted a pre-verdict motion for judgment as a matter of law (JMOL) under Federal Rule of Civil Procedure 50(a) on the issue of the invalidity relating to the '125 patent and the '540 patents. ECF No. 239 at 47:8–53:11. The Court held that there was not a legally sufficient evidentiary basis upon which a reasonable jury could have concluded that: claim 1 of the '125 patent was invalid based on any of Defendants' three prior-art grounds against that patent; or the asserted claims of the '540 patent were invalid based on one of Defendants' two prior-art grounds against that patent. *Id.* Defendants based these deficient prior-art grounds on system prior art—physical lighting tubes—that Defendants failed to introduce into evidence before evidence closed. *See id.*

On November 4, 2021, the Jury rendered a unanimous verdict, finding that Defendants infringed all Asserted Claims and that Defendants failed to prove that any Asserted Claim was invalid. ECF No. 230. The Jury awarded damages in the amount of $13,872,872 from CH and Ruising and $298,454 from Elliott and further found that CH and Ruising willfully infringed. *Id.*

On November 24, 2021, Plaintiffs moved for enhanced damages and a permanent injunction. ECF Nos. 233, 234. On December 2, 2021, Plaintiffs moved for attorneys' fees and entry of judgment. ECF Nos. 241, 242. The Court heard oral arguments on those motions on February 15, 2022. *See* ECF No. 279. Those motions are now ripe for judgment.

II. ENHANCED DAMAGES

Plaintiffs' Motion for Enhanced Damages, ECF No. 233, is **GRANTED-IN-PART**.

A. Legal Standard

Section 284 of Title 35 provides that, in a patent infringement case, "the court may increase the damages up to three times the amount found or assessed." 35 U.S.C. § 284. As the Supreme Court has remarked in the seminal *Halo* decision, "That language contains no explicit limit or condition, and we have emphasized that the word 'may' clearly connotes discretion." *Halo Elecs., Inc. v. Pulse Elecs., Inc.*, 579 U.S. 93, 103 (2016) (cleaned up). That discretion is not boundless and instead must be exercised "in light of considerations underlying the grant of that discretion." *Id.* (cleaned up). In interpreting those considerations, the Supreme Court appealed to the judiciary's 180-year history of awarding enhanced damages, in which courts have "generally reserved" enhancement for "egregious cases of culpable behavior." *Id.* at 104. Egregious cases typically involve, in the Court's opinion, conduct that is "willful, wanton, malicious, bad-faith, deliberate, consciously wrongful, flagrant, or—indeed—characteristic of a pirate." *Id.* at 103–04; *id.* at 107 ("[S]uch punishment should generally be reserved for egregious cases typified by willful misconduct.").

"Willfulness largely turns on intent, which is an issue reserved to the jury." *See WBIP, LLC v. Kohler Co.*, 829 F.3d 1317, 1341 (Fed. Cir. 2016). Once the jury finds that the defendant's infringement was willful, the Court must consider whether that alone justifies enhancement. According to the Federal Circuit, "*Halo* emphasized that subjective willfulness alone . . . can support an award of enhanced damages." *WesternGeco L.L.C. v. ION Geophysical Corp.*, 837 F.3d 1358, 1362 (Fed. Cir. 2016), *rev'd on other grounds*, 138 S. Ct. 2129, 201 L. Ed. 2d 584 (2018);

Halo, 579 U.S. at 105 ("The subjective willfulness of a patent infringer, intentional or knowing, may warrant enhanced damages, without regard to whether his infringement was objectively reckless."). Yet courts are vested with discretion to forbear enhancement under § 284 even in egregious cases, if that is what "the particular circumstances of" the case demand. *Id.* at 106; *cf. id.* at 111 (Breyer, J., dissenting) ("[W]hile the Court explains that 'intentional or knowing' infringement 'may' warrant a punitive sanction, the word it uses is *may*, not *must*. . . . It is 'circumstanc[e]' that transforms simple knowledge into such egregious behavior, and that makes all the difference.").

The Federal Circuit has endorsed consideration of the *Read* factors to "assist the trial court in evaluating the degree of the infringer's culpability and in determining whether to exercise its discretion to award enhanced damages at all, and if so, by how much the damages should be increased." *WCM Indus., Inc. v. IPS Corp.*, 721 F. App'x 959, 972 (Fed. Cir. 2018). As to burdens, the "party seeking enhanced damages under § 284 bears the burden of proof by a preponderance of the evidence." *WBIP*, 829 F.3d at 1339.

B. Discussion

In *Read Corp. v. Portec, Inc.*, the Federal Circuit established a list of factors for district courts to evaluate when considering whether an infringer's behavior warrants enhanced damages. 970 F.2d 816 (Fed. Cir. 1992). Although *Halo* likely overruled *Read*, the *Read* factors still serve as "useful guideposts" in the § 284 analysis. *See, e.g., Apple Inc. v. Samsung Elecs. Co.*, 258 F. Supp. 3d 1013, 1030 (N.D. Cal. 2017). As such, the Court uses *Read* as a tool in reviewing Defendants' conduct. The *Read* factors are: (1) whether the infringer deliberately copied the ideas or design of another; (2) whether the infringer, when it knew of the other's patent protection, investigated the scope of the patent and formed a good-faith belief that it was invalid or that it was not infringed; (3) the infringer's behavior as a party to the litigation; (4) defendant's size and financial condition; (5) closeness of the case; (6) duration of defendant's misconduct; (7) remedial action by the defendant; (8) defendant's motivation to harm; and (9) whether defendant attempted to conceal its misconduct. 970 F.2d at 827. The Court proceeds through each factor one by one.

1. *Read* Factor 1: Deliberate Copying

The first *Read* factor concerns whether Defendants deliberately copied Super Lighting's designs. The Court is not persuaded that Plaintiffs have shown any copying. While they detail Jack Jiang and Jun Yang's sojourn from Super Lighting to CH, Plaintiffs do not outright accuse those two of designing and developing the accused products to match Super Lighting's products. ECF No. 233 at 1–2, 17. That is, of course, the suggestion. But Plaintiffs do not offer evidence of how the accused products were designed and developed or who was involved. Defendants fill in the gaps, remarking that the bulk of Plaintiffs' infringement allegations for the '140 patent "relate to the use of an integrated circuit developed by third-party manufacturers . . . and purchased by CH." ECF No. 247 at 2. CH's corporate witness testified that CH has little understanding of the internal structure of those third-party-manufactured integrated circuits or how they work. *See* ECF No. 247-3 at 25:14–16. This evidence weighs against a finding of copying (at least for purposes of enhancement).

Plaintiffs' heavy reliance on documents found in CH's possession is not persuasive evidence of copying. It is undisputed that CH possesses confidential testing reports on Super Lighting tubes and a comparison of Super Lighting and CH tubes. As to the former, Plaintiffs do not tie the confidential Super Lighting testing reports to the design and development of the accused products. *See* ECF No. 247 at 3–4. As to the latter, in 2017 CH personnel drafted a one-page analysis comparing CH's accused tubes to Super Lighting's accused tubes, at Jack Jiang's request and with an eye, it seems, to features that the '140 patent happens to claim. ECF No. 233 at 17; ECF No. 225-6; ECF No. 237 at 140:18–142:5. Yet, as Defendants note, the analysis identifies several differences between the accused product and Super Lighting's product. ECF No. 247 at 2. The Jury heard from the engineer who produced the comparison: "Both [CH and Super Lighting] can satisfy the UL standard, but their suppliers are different, their schematics are different, their chip solutions are also different." ECF No. 237 at 142:6–10. And he denied ever copying or being asked to. *Id.* at 141:12–17. This cuts against a finding of copying.

The Court also agrees with Defendants that CH's comparison of the *finished* accused product to Super Lighting's product has little bearing on copying. It would be a different story if CH had used a similar comparison to guide the design and development of its accused products. But benchmarking your finished accused product against your competitor's product is not, in this Court's estimation, strong evidence of copying. Especially in an industry where, as Super Lighting's own expert conceded, it is common practice to review competitor products. ECF No. 239 at 116:22–24.

Considering all this evidence, the Court is not persuaded that Plaintiffs have sufficiently shown copying.

2. *Read* Factor 2: Good-Faith Belief Regarding Defenses

The second *Read* factor asks whether the defendants, when they learned of the relevant patents, investigated their scope and formed a good-faith belief that the patents were invalid or not infringed. The Court finds that CH and Ruising investigated the scope of the Asserted Patents, but the Court is not convinced that that investigation vested in Defendants a good-faith belief that the patents were invalid or not infringed. The Court holds that CH and Ruising only gained that belief after offering good-faith invalidity and noninfringement defenses in response to Super Lighting's complaint.

The Court instructed the Jury of certain facts pertinent to Defendants' investigation. Specifically, that CH and Ruising learned about the '140 patent on February 16, 2019, and the

’540 and ’125 patents in July 2019, and that they took “no actions other than to retain litigation counsel for this case on or about November 12, 2020.” ECF No. 226 at 20. The Court issued that instruction as a sanction, which Plaintiffs requested in response to inconsistencies in CH’s position regarding any opinions of counsel CH may have received related to the Asserted Patents. *See* ECF Nos. 176, 196. After the Court ordered that instruction from the bench, the parties negotiated its exact scope.

Some developments underlying that sanction are particularly relevant. Most notably, Defendants never substantively responded to Plaintiffs’ discovery requests regarding Defendants’ awareness of the Asserted Patents and any steps Defendants took once they gained that awareness. *See* ECF No. 176 at 3. Plaintiffs were surprised, then, to hear Jack Jiang, in a deposition conducted right before fact discovery closed, testify that he procured opinions of noninfringement and invalidity—covering Super Lighting’s entire patent portfolio—from Chinese counsel in mid-2019, well before CH responded to Super Lighting’s complaint. *Id.* Super Lighting filed suit against CH’s customer, MaxLite, in the U.S. District Court for the Central District of California in May 2019, prompting Jack Jiang’s investigation. *See id.* at 11 & n.15; *see also* Complaint, *Jiaxing Super Lighting Electric Appliance Co., Ltd. v. MaxLite, Inc.*, No. 2:19-cv-04047 (C.D. Cal. May 8, 2019). Guo Pengxin, CH’s director in charge of quality and certification, apparently helped CH’s Chinese counsel develop these opinions. ECF No. 176-2 at 83:15–24. Defendants consistently disclaimed any intent to use an opinion-of-counsel defense and—consistent with the Court’s instruction to the Jury—presented no evidence of Jack Jiang’s investigation to the Jury. The Court is not privy to the opinion of CH’s Chinese counsel but what the Court has heard about it inspires little confidence that it was sufficiently competent to engender a good-faith belief of noninfringement in CH and Ruising. Defendants’ waiver of the opinion-of-counsel defense further supports that suspicion.

The existence of the Chinese opinion does suggest that CH and Ruising were aware and concerned of the potential risks the Asserted Patents posed to Defendants' products. *Cf. Golden Blount, Inc. v. Robert H. Peterson Co.*, 438 F.3d 1354, 1369 (Fed. Cir. 2006) (finding that incompetent opinions of counsel and surrounding facts are properly considered evidence of willfulness). The Jury heard that CH and Ruising personnel issued warnings that chips in CH's products had some "patent risk." *See* ECF No. 237 at 204:12–205:13; *see also* ECF No. 238 at 155:10–156:7 (discussing a SWOT analysis CH performed that suggested that its products were at risk, generally, for infringing patents). Those warnings were not specific to any of the Asserted Patents—but the products tagged with the "risk" label infringe the '140 patent, or so the Jury determined.

Shortly before it initiated this Action, Super Lighting attempted to notify CH that CH was infringing the Asserted Patents. On October 2, 2019, Super Lighting wrote to CH's CEO Caiying Gan and raised specific instances of CH's infringement of the Asserted Patents. *See* ECF No. 233 at 4. CH did not respond so Super Lighting wrote again on November 4, 2019. *See id.* CH was again silent. Super Lighting emailed Ms. Gan a third time on December 22, 2019. *See id.* Receiving no response, Super Lighting filed this Action in January 2020. CH did not respond to Super Lighting's complaint until December 2020, a month after it finally retained litigation counsel. *See* ECF No. 238 at 134:6–22, 145:2–10.

The Court instructed the Jury that, when evaluating Defendants' willfulness, it should consider whether Defendants had established a good-faith belief of non-infringement or invalidity. ECF No. 226 at 19–20. The Jury considered Defendants' evidence and nevertheless found CH's infringement to be willful. In this Court's opinion, that favors enhancement. *See Vectura Ltd. v. GlaxoSmithKline LLC*, No. CV 16-638-RGA, 2019 WL 4346502, at *4 (D. Del. Sept. 12, 2019)

("I agree that, in view of the willful infringement verdict, Defendants did not have a good-faith belief of noninfringement."); *Bio-Rad Lab'ys Inc. v. 10X Genomics, Inc.*, No. 15-CV-152-RGA, 2019 WL 3322322, at *10 (D. Del. July 24, 2019) (same), *vacated on other grounds*, 967 F.3d 1353 (Fed. Cir. 2020); *Alfred E. Mann Found. for Sci. Rsch. v. Cochlear Corp.*, No. CV 07-8108 FMO (SHX), 2018 WL 6190604, at *25 (C.D. Cal. Nov. 4, 2018) (finding that the jury considered evidence of the defendant's good faith but found it unpersuasive), *aff'd*, 798 F. App'x 643 (Fed. Cir. 2020). The Court finds little of the evidence above to weigh against enhancement under this factor.

3. <u>*Read* Factor 5: Closeness of the Case</u>

The fifth *Read* factor concerns how "close" the case was.[3] This factor favors enhancement, although only slightly. The speed and lopsidedness of the Jury's verdict weighs in favor of enhancement while the fact that Defendants' defenses survived to trial weighs against enhancement.

The Jury returned a unanimous verdict in less than two hours of deliberating, concluding that Defendants infringe all the Asserted Patents, that the Asserted Patents were not invalid, and that CH and Ruising's infringement was willful. *See* ECF No. 279 at 40:12–13. As to damages, the Jury gave Plaintiffs exactly what they asked for. Other courts have enhanced damages based in part on the length of the jury's deliberations and the asymmetry of the outcome. *See, e.g.*, *EagleView Techs., Inc. v. Xactware Sols., Inc.*, 522 F. Supp. 3d 40, 52 (D.N.J. 2021); *Chamberlain Grp., Inc. v. Techtronic Indus. Co. Ltd.*, 315 F. Supp. 3d 977, 1014 (N.D. Ill. 2018). The Court will do the same here but to some lesser degree, appreciating that this Jury's workload was

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[3] The Court takes this *Read* factor out of order, finding it related to the second factor.

relatively light, which could account for the brief deliberations. As to core issues, they only had to decide direct infringement for a single product and invalidity for two of the three Asserted Patents.

Plaintiffs contend that this factor more heavily favors enhancement because "virtually every argument CH presented was exposed as a sham." ECF No. 233 at 17. The Court disagrees with the premise. Plaintiffs most compelling evidence on this point is CH's stipulation to infringement for most of the accused products at a late stage in this Action, after the parties had already prepared expert reports. To be sure, that stipulation is weighty—this would have been a closer case had CH presented a non-frivolous noninfringement theory at trial. As this Court put it during oral arguments: "[I]f you're going to trial, would you rather have a noninfringement defense or an invalidity defense? I don't think anyone would pick, in most cases, the invalidity defense as what they would want to be their lead defenses." ECF No. 279 at 66:21–67:2. Yet CH's stipulation does not render the other defenses CH presented at trial a "sham." If they were baseless, Plaintiffs could have convinced this Court to dispose of this Action at summary judgment. They did not even try—the Court did not receive any motions for summary judgment as to the infringement or invalidity issues CH presented to the Jury. Accordingly, the Court is not inclined to deem CH's trial defenses baseless.

The Court cannot avoid remarking on the pre-verdict JMOL that disposed of CH's invalidity case as to the '125 patent. Super Lighting contends that this is a "true rarity in a patent case" and remarks on how it warned CH before trial that CH did not have sufficient evidence to mount an invalidity defense as to the '125 patent. ECF No. 233 at 18. The nature of the JMOL ruling attenuates its impact under this factor. In rendering this ruling, the Court did not opine upon the merits of the prior art combination CH proffered; it only determined that defense counsel did not get critical system art—or representative pictures—into evidence before Defendants closed their case. *See* ECF No. 239 at 47:8–53:9; *cf. Wapp Tech Ltd. P'ship v. Seattle SpinCo, Inc.*, No. 4:18-CV-469, 2021 WL 1574714, at *3 (E.D. Tex. Apr. 22, 2021) (upholding willfulness verdict despite JMOL dismissing invalidity defense because the JMOL sprung from the defendant's bad time management and not merits of the defense). If that evidentiary snafu was inevitable, as Plaintiffs seem to suggest, Plaintiffs would (or should) have raised it with the Court *before* reaching trial—saving everyone time, energy, and resources. Their failure to do so speaks volumes.

In addition, the impact of the JMOL ruling is diminished given that it resolved invalidity for only one patent—it did not undercut theories applied to the two other Asserted Patents. Plaintiffs allege that the prior art tubes that Plaintiffs could not authenticate were "the heart of [Defendants'] invalidity case." ECF No. 279 at 24:21–23. But the Court agrees with Defendants that "the bulk of the case related to the '140 patent." ECF No. 247 at 5. The distribution of asserted patent claims bears that out, as does, as the Court describes later, much of the discussion around the preliminary injunction focused on the shock-protection offered by the '140 patent's invention. *See infra* IV.B.2.

Also relevant is Defendants' decision to drop its inequitable conduct claims by stipulation right before trial. ECF No. 233 at 6. The number of meritorious defenses levied against an ultimately successful infringement claim may speak to the closeness of a case. Generally, the more defenses, the closer the case. On the other hand, when defenses fall away, a case may become less close. CH's inequitable conduct claims were so important to CH, it issued a press release describing how it was able to add them to its answer. *See infra* Section II.B.9. And though Defendants now conveniently argue that they dropped those inequitable conduct allegations because they "were most strong with respect to the" five patents that Plaintiffs dropped before trial, ECF No. 279 at 68:2–6, Defendants were not so careful to distinguish the strength of their inequitable conduct allegations patent-by-patent when issuing a press release for the market's review. The Court finds that dropping such an ostensibly significant defense *must* mean that the case became less close.[4] But because the defenses Defendants presented at trial were not frivolous, the Court is not convinced that dropping the inequitable conduct claim had a substantial impact under this factor.

None of the other gripes Plaintiffs raise under this factor are particularly persuasive. First, Plaintiffs ding Dr. Zane, Defendants' noninfringement expert, for resting his noninfringement position as to the LT2600 on mere criticism of the infringement opinion of Dr. D'Andrade, Plaintiffs' expert. ECF No. 233 at 17. The Court agrees with CH, however, that Dr. Zane analyzed the same documents and testing Dr. D'Andrade analyzed to draw a conclusion contrary to Dr. D'Andrade. ECF No. 247 at 4. Dr. Zane did not have to "conduct his own reverse engineering" to make this a close case (though it certainly would have helped). *Id.*

Second, Plaintiffs claim that CH deprived its technical experts of evidence of CH's copying and those same experts ignored evidence of commercial success. ECF No. 233 at 17. As to copying, CH states that it was Super Lighting's burden to prove copying as a secondary consideration of non-obviousness and CH's experts did not need to consider such evidence, especially where Super Lighting's expert did not even opine on that fact. ECF No. 247 at 6. CH's position is persuasive.

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[4] For comparison, CH argues that this Court must consider Super Lighting dropping several infringement claims pretrial, including one on which Defendants moved for summary judgment. ECF No. 247 at 6. The Court does not find, and Defendants have not sufficiently explained, how Super Lighting dropping several patents from this Action speaks to how close the case was as to the patents that made it to trial.

Third, Plaintiffs allege that CH's strongest defense constituted an obvious combination involving art the U.S. Patent and Trademark Office (USPTO) had already considered. ECF No. 233 at 17. Yet there is no evidence that the USPTO considered CH's combinations (or even a sufficiently comparable combinations). *See* ECF No. 247 at 4. The Court will not find that this case is not close merely because the USPTO reviewed one reference in an infringer's obvious combination.

This factor favors enhancement in view of the Jury's quick and lopsided decision. The Court will also not deny that Defendants' dropping their noninfringement case right before trial weighs in favor of enhancement. But this factor does not tilt overwhelmingly in Plaintiffs' favor at least because Defendants put on an invalidity case (and noninfringement for one product) at trial that was not frivolous or even exceptionally weak.

4. <u>*Read* Factor 3: Infringer's Litigation Behavior</u>

The third *Read* factor concerns the infringers' behavior as a party to the litigation. The Court's analysis of this factor overlaps significantly with its exceptionality analysis under § 285, above. As explained more thoroughly there, the Court finds that Defendants behaved unreasonably in several instances. *See infra* Section III.B.

5. <u>*Read* Factor 4: Defendant's Size and Financial Condition</u>

The fourth *Read* factor asks the Court to evaluate Defendants' size and financial condition. CH contends that trebling damages to $42 million "would profoundly impact CH's business and production. In fact, trebling the damages would ***exceed*** the incremental profit CH made from any infringing sales by almost $10 million." ECF No. 247 at 18. CH has not represented that trebling would drive it out of business and Plaintiffs remark that "CH made more than double that $42 million by continuing to infringe." ECF No. 255 at 8. In addition, the Court does not consider CH and Ruising an unsophisticated party as it pertains to legal matters; Jack Jiang testified that their

Chinese counsel is a "famous law firm that we have been working with for about seven or eight years." ECF No. 176-2 at 66:9–14. This factor does not discourage the Court from enhancement.

6. *Read* Factor 6: Duration of Defendant's Misconduct

The sixth *Read* factor asks the Court to consider the duration of Defendants' misconduct. It seems to this Court that CH and Ruising were concerned enough about the threat the Asserted Patents posed that they sought an opinion from Chinese counsel in mid-2019. *See supra* Section II.B.2. They nevertheless continued infringing and have not stopped yet. The Court is dubious that Super Lighting's pre-suit emails to CH's CEO did not give CH and Ruising actual notice of their infringement. Indeed, Jack Jiang's pre-suit investigation may suggest that CH and Ruising knew of their infringement risk *before* those notice letter. Nevertheless, this factor does not weigh heavily in favor of enhancement because Super Lighting likely only knew for less than 18 months, if that. *WCM Indus., Inc.*, 721 F. App'x at 973 (holding that the duration of misconduct likely weighs against enhancement where the patents issued a short time before the filing of the lawsuit).

7. *Read* Factor 7: Remedial Actions

The seventh *Read* factor concerns whether Defendants took remedial action. As other courts have explained, this factor concerns "whether conduct during the pendency of the suit evinces an unrepentant defendant." *Acantha LLC v. DePuy Synthes Sales Inc.*, 406 F. Supp. 3d 742, 761 (E.D. Wis. 2019); *Creative Internet Advert. Corp. v. Yahoo! Inc.*, 689 F. Supp. 2d 858, 869 (E.D. Tex. 2010) ("This factor looks to whether the defendant ceased the sale of the infringing product during the pendency of the litigation."). CH all but concedes it has taken no remedial action but excuses itself on the ground that it has asserted good-faith defenses and will continue to do so in post-verdict motions and on appeal. ECF No. 247 at 19 (citing *Acantha*, 406 F. Supp. 3d at 761). That excuse, at least as to post-verdict conduct, holds little weight here. It is difficult for Defendants to maintain a good-faith belief that they do not infringe until either this Court, or a higher court, vacates the Jury's verdict. Or at least the Court will presume as much given that a jury verdict considerably narrows their ability to ultimately prevail in this dispute.

8. <u>*Read* Factor 8: Defendant's Motivation</u>

The eighth *Read* factor asks whether the Defendants were motivated to harm Plaintiff. Super Lighting contends that its status as CH's archrival motivated CH to harm Super Lighting by committing infringement. ECF No. 233 at 20. The Court is persuaded that the competition between Super Lighting and CH is fierce; it drove CH to poach Jack Jiang from Super Lighting by offering "unusually large benefits"—a rent-free house, a free office, and the power to run Ruising. *Id.* at 1, 20. Moreover, CH produced Super Lighting's confidential documents—testing reports—relating to lamp tubes. *Id.* at 2. CH never explained why it had those documents. *Id.* at 2. All it could say was that some of them were dated after Jack Jiang and Jun Yang arrived at CH. *See* ECF No. 241 at 2 n.2. CH could not explain away Jack Jiang's possession of Super Lighting's customer lists, though. ECF No. 233 at 2. All this leads to a conclusion that CH and Super Lighting were rivals, potentially even "archrivals," and indicates CH *did* have a motivation to harm Super Lighting.

The notion that "infringement by a direct competitor in [a small] market mitigates in favor of enhanced damages," *TruePosition Inc. v. Andrew Corp.*, 611 F. Supp. 2d 400, 412 (D. Del. 2009), *aff'd*, 389 F. App'x 1000 (Fed. Cir. 2010), is compelling here. *EagleView Techs., Inc. v. Xactware Sols., Inc.*, 522 F. Supp. 3d 40, 54 (D.N.J. 2021). "Additionally, courts are even more willing to find that this factor should enhance damages when 'the evidence supports the conclusion that [the infringer] preferred taking the risk of infringement over designing a non-infringing device.'" *Id.* (quoting *Polara Eng'g, Inc. v. Campbell Co.*, 237 F. Supp. 3d 956, 994 (C.D. Cal. 2017), *aff'd in part, vacated in part on other grounds*, 894 F.3d 1339 (Fed. Cir. 2018)). CH stipulated to infringement and continued infringing. The Jury found CH liable for infringement—even willfully so—and yet CH has continued infringing. Even if the Court found that CH was not motivated to harm Super Lighting, CH's continued infringement evinces at least a reckless disregard for the harm it has and continues to cause to a rival. The Court therefore finds that this factor favors enhancement.

9. *Read* Factor 9: Infringer's Concealment

The final *Read* factor concerns whether Defendants attempted to conceal their misconduct. The Court agrees with CH that CH openly sold the accused products, and continues to do so, without any attempt to physically conceal the infringing components. And Plaintiffs adduce no evidence that CH kept any data about infringing sales back. Indeed, it seems the parties are continuing to keep an account of those sales.

The Court must also consider, however, CH and Ruising's withholding information relevant to willfulness—specifically, Jack Jiang's investigations into Super Lighting's patent portfolio in mid-2019—until late in the case. Moreover, the Court finds that CH and Ruising meant to improve their post-complaint market position by publicly obfuscating their true infringement risk. For example, this Court, after finding that adding claims of unclean hands and inequitable conduct would not be futile, granted Defendants leave to amend their answer to Super Lighting's complaint. *See* ECF No. 162. Yet Jack Jiang took to WeChat, a popular social platform in China, and described that ruling as an "acknowledgement that [Super Lighting's] patents were acquired illegally." *See* ECF No. 233 at 12. That is a misrepresentation of this Court's order. *See* ECF No. 137 at 40:23–41:3 (discussing this issue when first raised). Jack Jiang and his counsel at Radulescu LLP also issued a press release through a proxy, in which they described the Court's ruling on the amendment in more accurate terms. ECF No. 233-5. That release, however, outlined CH's inequitable conduct theory in great and salacious detail. One would think from reading the announcement that Radulescu had unearthed a smoking gun, painting a generous picture. In reality, CH's inequitable conduct theory as to the Asserted Patents would not survive to trial. ECF No. 233 at 6.

10. <u>Conclusion</u>

The Court finds that this case is egregious and therefore enhancement is warranted here based on: the Jury's willfulness finding; the fact that this case was not very close; CH and Ruising's disregard for their discovery obligations; Jack Jiang's mischaracterization of this Court's ruling regarding inequitable conduct; Jack Jiang and Radulescu's glowing press release; and CH and Ruising's motivation to harm Plaintiffs. The Court finds that doubling the damages award is adequate punishment for the level of culpability CH and Ruising have shown. Yet the Court finds it unjust to apply that multiple to an award covering the entire damages period. "Culpability . . . is generally measured against the actor's knowledge at the time of the challenged conduct." *Halo*, 579 U.S. at 114. As indicated above, the Court is satisfied that Defendants developed a good-faith belief that they were not infringing by the time they filed an answer to Plaintiffs' complaint. Accordingly, the Court will not cognize Defendants' infringement as willful or culpable for the period between filing an answer and receiving an adverse jury verdict. The Court will not multiply any damages attributed to CH and Ruising accrued during that period.

That said, a defendant "cannot insulate itself from liability for enhanced damages by creating an (ultimately unsuccessful) invalidity defense for trial." *WBIP*, 829 F.3d at 1340. As such, damages that CH and Ruising accrued outside that period, and after CH and Ruising first learned of the Asserted Patents—that is, the date CH and Ruising learned of the '140 patent according to the jury charge—will be doubled. *See Stryker Corp. v. Davol Inc.*, 234 F.3d 1252, 1260 (Fed. Cir. 2000) (affirming a tailored approach to enhancing damages based on culpability during a given period). The Court finds that the date CH and Ruising learned of the '140 patent is an appropriate starting point given the Court's instruction as to CH and Ruising's awareness of the

Asserted Patents, the Jury's unbounded willfulness finding, and Jack Jiang's admissions regarding the timing of his pre-suit investigation regarding the Asserted Patents.

III. ATTORNEYS' FEES

Plaintiffs' Motion for Attorneys' Fees, ECF No. 241, is **DENIED**.

A. Legal Standard

1. 35 U.S.C. § 285

Pursuant to the Patent Act, in "exceptional cases," a district court "may award reasonable attorney fees to the prevailing party." 35 U.S.C. § 285. An "exceptional case" is "simply one that stands out from others with respect to the substantive strength of a party's litigating position . . . or the unreasonable manner in which the case was litigated." *Octane Fitness, LLC v. ICON Health & Fitness, Inc.*, 572 U.S. 545, 554 (2014).

District courts must determine whether any particular case is "exceptional" in a "case-by-case exercise of their discretion, considering the totality of the circumstances." *Id.* Whether a case is "exceptional" or not "is a factual determination," *Forcillo v. Lemond Fitness, Inc.*, 168 F. App'x 429, 430 (Fed. Cir. 2006), and the court must make its determination by a "preponderance of the evidence," *Octane Fitness*, 572 U.S. at 558 (rejecting the prior requirement that a patent litigant establish its entitlement to fees under § 285 by "clear and convincing" evidence).

In assessing the "totality of the circumstances," courts may consider factors such as "frivolousness, motivation, objective unreasonableness (both in the factual and legal components of the case) and the need in particular circumstances to advance considerations of compensation and deterrence." *Id.* at 554 n.6 (citing *Fogerty v. Fantasy, Inc.*, 510 U.S. 517, 534 n.9 (1994) (addressing a similar fee-shifting provision in the Copyright Act)). A party's conduct need not be independently sanctionable to warrant an award of fees under § 285; however, fee awards should not be used "as a penalty for failure to win a patent infringement suit." *Munchkin, Inc. v. Luv n' Care, Ltd.*, 960 F.3d 1373, 1378 (Fed. Cir. 2020) (quoting *Octane Fitness*, 572 U.S. at 548).

2. 28 U.S.C. § 1927

Under 28 U.S.C. § 1927, "[a]ny attorney or other person admitted to conduct cases in any court of the United States . . . who so multiplies the proceedings in any case unreasonably and vexatiously may be required by the court to satisfy personally the excess costs, expenses, and attorneys' fees reasonably incurred because of such conduct." Conduct is "unreasonable and vexatious" "if there is evidence of the persistent prosecution of a meritless claim and of a reckless disregard of the duty owed to the court." *Morrison v. Walker*, 939 F.3d 633, 637–38 (5th Cir. 2019) (quotations omitted). Under § 1927, a court may award attorney fees, costs, and expenses that were "reasonably incurred" because of the attorney's misconduct. *Id.* at 637.

B. Discussion

Plaintiffs take a kitchen-sink approach to argue their entitlement to attorneys' fees. As a threshold matter, the Court appreciates the Jury's willfulness determination but, again, that is not dispositive of Plaintiffs' entitlement to fees under § 285. *SiOnyx LLC v. Hamamatsu Photonics K.K.*, 981 F.3d 1339, 1354 (Fed. Cir. 2020). The Court starts with what it considers the most uncommon conduct: CH and Ruising's disregard for their discovery obligations; misrepresentations made to the public regarding this Court's order on inequitable conduct; and Defendants' failure to put its system prior art into evidence. It then moves to conduct the Court finds less objectionable. The Court concludes that "the [Jury]'s finding of willful infringement is not determinative of whether [this] case is exceptional under § 285, and that [Defendants'] litigation conduct was consistent with an aggressive," and sometimes inept, "defense but was not otherwise uncommon or exceptional." *Id.*

1. Defendants' Objectionable Litigation Conduct

a. *Defendants' Discovery Obligations*

Plaintiffs adduced evidence suggesting Defendants harbored a disregard for its discovery obligation in this Action. Plaintiffs highlighted this disregard for the Court during a discovery hearing on July 12, 2021, in which Plaintiffs identified discrepancies that arose when deposing key CH and Ruising witnesses. *See* ECF No. 137.

For example, Plaintiffs deposed Caiying Gan, at which point it become evident that she had not searched for any documents pertinent to this Action—despite her position as CH's CEO. *See id.* at 28:6–30:11. Indeed, she testified that no one had asked her to search for *or preserve* any relevant documents.[5] *Id.*

Plaintiffs also deposed Jack Jiang, who revealed that he procured opinions on the Asserted Patents in mid-2019. *See supra* Section II.B.2. This was the first Plaintiffs learned of anything

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[5] Plaintiffs also contend that CH engaged in spoliation of evidence because, although Caiying Gan confirmed that Super Lighting sent notice letters to her email address, she could not locate them when conducting a search of her email account, at Super Lighting's counsel's request, during her deposition. ECF No. 233 at 10; ECF No. 241 at 8–9. Plaintiffs assert that Ms. Gan's email account does not have an auto-delete function, so the only explanation for why she could not find the notice letters is because someone deleted them. ECF No. 233 at 10; ECF No. 241 at 8–9.

Defendants counter that, Ms. Gan, who testified that she does not read any of her emails, was given fifteen minutes to perform an "inexpert search" for an eighteen-month-old email, written in a language she does not understand, all while she was experiencing technical difficulties *and* being asked questions by Super Lighting's counsel. ECF No. 247 at 8. Yet the Court notes that Jun Yang, Ruising personnel, testified that he could not find the notice letters when he searched Ms. Gan's email on her phone yet found it when searching the computer of another CH employee. ECF No. 237 at 207:12–208:2. The Court is, therefore, dubious that Ms. Gan's inability to locate Plaintiffs' letters under challenging circumstances leads to the conclusion that CH must have deleted these notice letters. Nor is the Court confident in the thoroughness of Jun Yang searching Ms. Gan's phone. The Court further agrees with CH that, "If Plaintiffs genuinely believed that such conduct gave rise to a spoliation claim, they should have sought a spoliation instruction." *Id.* In stating that, the Court is not finding that CH did not have pre-suit notice of the Asserted Patents or their infringement, through the emails or otherwise. Indeed, the Court finds it more likely than not that CH had that notice.

approaching a formal investigation into the Asserted Patents, despite having served discovery requests that should have elicited this information much earlier in the case. *See id.* When asked why Defendants had not produced anything related to this opinion, Mr. Jiang stated: "It's very simple. No one asked us about it. And we also didn't know what documents we were supposed to provide." ECF No. 176-2 at 67:9–15. Mr. Jiang also testified the Guo Pengxin, director in charge of quality and certification for CH, helped outside counsel develop these opinions. *Id.* at 83:15–24. Yet Guo Pengxin denied any involvement in any such opinions; Mr. Jiang supposed that Mr. Pengxin was mistaken, likely a result of stress and concern "that [he] might lose [his] job" if the deposition did not go well. *Id.* at 83:25–85:10. This inconsistency adds to the Court's concern.

The Court heard arguments regarding Ms. Gan and Mr. Jiang's testimony and Defendants' failure to meet their discovery obligations and ordered additional document productions and more time for Plaintiffs to depose Ms. Gan and Mr. Jiang. ECF No. 137 at 27:11–18, 33:14–35:3. At that time, the undersigned refused to shift the costs for the additional depositions to Defendants. *Id.* at 37:3–23. Nevertheless, Defendants' disregard for their discovery obligations is troubling.[6]

b. *Jack Jiang's Public Statements*

At the same hearing, the Court expressed concern with Jack Jiang making public statements that did not accurately characterize this Court's ruling on Defendants' inequitable conduct claims. *Id.* at 40:23–41:3. That too is concerning.

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[6] Plaintiffs raise other discovery-related issues of lesser concern that the Court dealt with in short order. For example, the Court: excluded documents that Defendants produced from Lumixess and Maxlite; and excluded a late-identified Maxlite witness. *See* ECF No. 233 at 11; ECF No. 241 at 11–12. Plaintiffs also remark how CH initially withheld gross profit numbers for the accused lamps, stating that it did not track such numbers, before ultimately producing them. ECF No. 233 at 10; ECF No. 241 at 9. The Court is satisfied with Defendants' contention that translation issues caused this misunderstanding, ECF No. 251 at 8–9, and that Defendants' counsel undertook a reasonable investigation as to this information, ECF No. 279 at 94:8–25.

c. *The Court's JMOL*

Maybe the most extraordinary example of Defendants' conduct were the events surrounding the Court's ruling, in the middle of trial, that Defendants had failed to prove invalidity as to the '125 patent and one of two grounds of the '540 patent, all of which rested on tube lamps that were purported to be prior art. Dr. Lebby, Defendants' invalidity expert, propounded these invalidity grounds and testified that he had no personal experience with those tubes and he had not personally inspected them prior to issuing his report. *See* ECF No. 241 at 6. Rather, he had been provided photographs of teardowns of the prior art tubes; he did not know who took the photographs, when or where they were taken, or the qualifications of the person performing the teardown.[7] *See id.*

At 7:00 PM the night before Dr. Lebby's trial testimony, CH served over 100 demonstratives containing new, never-before-disclosed photographs of the prior art tubes, along with (apparently) relevant commentary. *See* ECF No. 241 at 13. Defendants contend that Dr. Lebby needed these photos for demonstrative purposes because the tube lamps were proving "unwieldy." ECF No. 251 at 14–15. That excuse holds little water where Defendants already had photographs of the tubes—the photographs Dr. Lebby's report relied on in place of the physical tubes themselves. The Court finds it more likely that Defendants may have been intending to shore up issues related to authenticating the photographs in Dr. Lebby's report. Yet the morning of Dr.

[7] The parties hotly debated the source of the photographs. At trial, Defendants alleged that they had an affidavit showing that Defendants' former counsel at Radulescu LLP took the photographs, but the affidavit only shows that possession of the physical tubes themselves passed from Radulescu to Defendants' current counsel. *See* ECF No. 241 at 13; ECF No. 244-7. The Court also *limined* out any suggestion that the person who took the photographs had a criminal record, which was a line of question down which Plaintiffs took Dr. Lebby during his deposition. *See* ECF No. 159 at 3.

Lebby's testimony, CH quickly agreed it would not use the new photographs. ECF No. 238 at 32:3–7. It did so with almost no argument, to the great surprise of Plaintiffs' counsel who had likely spent significant time—late at night and into the early morning—reviewing and preparing to respond to the new photographs and any attached commentary. *Id.* at 32:9–33:8. Thus, the new photographs wasted Plaintiffs' counsel time in the middle of trial and accomplished *nothing* else. ECF No. 241 at 13 ("This overhaul of Dr. Lebby's opinions, which Super Lighting detailed for the Court in the wee hours of the morning, forced Super Lighting['s] counsel to stay up all night and was clearly done to prejudice Super Lighting's cross-examination."); ECF No. 279 at 19:2–6 ("Mr. Reid and others on our team spent the entire night going through everything.").

Once Dr. Lebby took the stand, he commented on the photographs in his report but Defendants never introduced them as evidence. *See* ECF No. 241 at 7. So when Super Lighting sought JMOL on the alleged prior art products, CH was unable to point to any record evidence supporting its invalidity case as to the '125 patent and one ground of the '540 patent. The Court granted JMOL. *See id.*

Defendants' counsel's conduct through this chain of events was not reasonable. It shows a disregard for opposing counsel's time and a lack of diligence regarding evidentiary issues in the face of relevant warnings from opposing counsel. *See* ECF No. 233 at 18 (alluding to a pre-trial warning letter).

2. <u>Defendants' Other Litigation Conduct</u>

a. *Dropped Defenses*

Plaintiffs contend that counterclaims and defenses to infringement that Defendants eventually dropped were "meritless." The Court cannot agree. First are the noninfringement opinions that CH's experts, Dr. Zane and Dr. Lebby, prepared before CH dropped those defenses. *See* ECF No. 241 at 5–6; ECF No. 152 at 20:15–22:9 (reading the narrowing agreement into the record). Plaintiffs take umbrage with Dr. Zane's dropped noninfringement theories as to the '140 patent, which relied on an interpretation of the claims that Dr. Zane admitted would exclude preferred embodiments.[8] ECF No. 241 at 5. Certainly, courts should "interpret claim terms in a way that excludes embodiments disclosed in the specification" only in rare circumstances. *Oatey Co. v. IPS Corp.*, 514 F.3d 1271, 1276 (Fed. Cir. 2008); *Elekta Instrument S.A. v. O.U.R. Sci. Int'l, Inc.*, 214 F.3d 1302, 1308 (Fed. Cir. 2000). It is not clear to the Court whether this is that rare case. That is, it is not "apparent from the face of [the] patent" whether this noninfringement defense is reasonable or unreasonable. *Halo*, 579 U.S. at 114 (Breyer, J., dissenting).

Second is CH's inequitable conduct defense: "CH filed over 150 pages of inequitable conduct allegations against Super Lighting, claiming everything from deliberate withholding from the PTO to improper inventors." ECF No. 241 at 4. Super Lighting argues that aspects of that defense turned on "trivialities" and forced Super Lighting: to respond to CH's motion to amend the inequitable conduct counterclaims into the case; to answer those counterclaims; and to address them in its validity expert report. *Id.* at 5. Only then did CH drop those allegations. Defendants respond that it was not a coincidence that Plaintiffs "dropped most of the patents targeted by those allegations" at the same time. ECF No. 251 at 8. Plaintiffs reply that it did not drop those patents because "of any particular defenses." ECF No. 271 at 3. The more salient point, in this Court's estimation, is that CH "abandoned its opportunity to assert unclean hands or inequitable conduct, not just against the patents" that Plaintiffs dropped, but also against "the three patents that were presented to the jury." *Id.* at 4.

[8] Plaintiffs further contend that Dr. Zane admitted his interpretation would make the '140 patent impossible to practice but the Court cannot discern any such admission in Dr. Zane's deposition transcript. *See* ECF No. 241-7 at 86:10–17, 87:4–20.

The Court is cognizant that "the mere fact that an issue was pleaded and then dropped prior to trial does not in itself establish vexatious litigation" supporting a finding of exceptionality. *Beckman Instruments, Inc. v. LKB Produkter AB*, 892 F.2d 1547, 1551 (Fed. Cir. 1989); *see also Medtronic Navigation, Inc. v. BrainLAB Medizinische Computersysteme GmbH*, 603 F.3d 943, 959 (Fed. Cir. 2010) ("A decision by a party to narrow its case for presentation to a jury does not generally suggest manipulation of the litigation process."). Plaintiffs have not persuaded this Court that Defendants' dropped claims and defenses were objectively unreasonable. *See Mach. Corp. of Am. v. Gullfiber AB*, 774 F.2d 467, 471 (Fed. Cir. 1985) ("[O]ne should not be penalized for merely defending or prosecuting a lawsuit."). Dr. Zane's theory regarding the '140 patent is troubling but it is a challenge to adjudge its merits in this limited context. It is telling that Plaintiffs were not confident enough in the alleged weakness of Dr. Zane's theory to move for summary judgment on the issue.

Beyond that, the Court detects no motive from the circumstances surrounding the claims or defenses, such as the timing of CH's streamlining, that would suggest that CH committed litigation misconduct. *Cf. Kirtsaeng v. John Wiley & Sons, Inc.*, 579 U.S. 197, 209 (2016) (holding, in the context of a fee-shifting statute for copyright claims, that "a court may order fee-shifting because of a party's litigation misconduct, whatever the reasonableness of his claims or defenses").

b. *Delay & Avoid*

Plaintiffs contend that CH and its original counsel schemed to delay this Action and/or avoid litigating it in this District. For that proposition, Plaintiffs rely on what if refers to as the "DELAY and AVOID" email, in which CH's original counsel, David Radulescu from Radulescu LLP, told Jack Jiang that he was evaluating whether: CH could avoid litigating this dispute in Texas or the United States altogether; or CH could delay litigating in Texas for more than a year if Super Lighting fails to serve CH. *See* ECF No. 233 at 5; ECF No. 241 at 4. Even if CH interpreted the email as offering advice or instruction—as opposed to a status update—and even if CH followed through on it, the suggested course of conduct is not far from standard operating procedure for foreign defendants in a patent infringement case. Counsel does not cross any ethical boundaries by recommending that its client avoid forums counsel perceives as unfavorable.[9] Nor is it, as a general proposition, improper for a foreign defendant to insist that plaintiff serve it via the Hague Convention. *See* ECF No. 266 at 12–13; *Sheets v. Yamaha Motors Corp.*, 891 F.2d 533, 537 (5th Cir. 1990) ("Thus, because the service that plaintiff attempted fell squarely within the scope of Hague Convention, insisting on service pursuant to its provisions was warranted by existing law."). CH was not "dodging" service, as Super Lighting would have this Court believe. Under Plaintiffs' rationale, an attorney acts unethically whenever it advises its client to reject a request to waive service or whenever it opposes a motion for leave to effect alternative foreign service, thereby prolonging litigation. *See* ECF No. 255 at 3 (citing Texas Disciplinary Rule of Professional Conduct 3.02). The Court disagrees.

At trial, Plaintiffs attempted to impeach Mr. Jiang after he testified that CH did not have "a strategy of dodging service and avoiding litigation in Texas." ECF No. 233 at 5; ECF No. 241 at n.5. Plaintiffs posited then, as they do now, that the "DELAY and AVOID" email contradicts Mr. Jiang's testimony—that Plaintiffs caught Jack Jiang "lying on the witness stand." ECF No. 233 at 5; ECF No. 255 at 1. That is a step too far.

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[9] Indeed, the U.S. Court of Appeals for the Federal Circuit has recently reinvigorated 28 U.S.C. § 1404(a), all but encouraging accused infringers to seek transfer to venues some perceive to be more favorable.

First, Super Lighting's briefing does not accurately characterize Mr. Jiang's testimony. Neither counsel's question nor Mr. Jiang's answer are directed to "dodging" service or delay. Super Lighting's counsel asked Mr. Jiang whether Defendants "have a strategy of – of avoiding being forced to litigate in Texas after you were sued." ECF No. 238 at 148:13–16. Mr. Jiang replied: "That is not the case at all." *Id.* at 148:22. Mr. Jiang could not be caught lying on the stand about dodging service or delaying this Action because he did not testify to either issue.

Second, the "DELAY and AVOID" email is not evidence that CH had a strategy of avoiding litigating this Action in Texas, making Mr. Jiang a liar. The "DELAY and AVOID" email merely reflects that Radulescu was "evaluating potential options" to avoid Texas. *See* ECF No. 233 at 5. That is not evidence of Radulescu's ultimate recommendation on the issue—and even if it was, there is no evidence that CH or Jack Jiang adopted that recommendation. To the contrary, CH did not move to dismiss this Action on jurisdictional or *forum non conveniens* grounds or seek transfer to a more convenient forum. *See* ECF No. 279 at 90:20–91:10 (explaining that by "avoid," Mr. Radulescu meant contemplating the propriety of this Court's jurisdiction over CH). If Defendants' strategy was to avoid litigating in Texas, the Court cannot discern what steps they took to implement it. For the foregoing reasons, the Court is not convinced that this email or Mr. Jiang's subsequent testimony amounts to misconduct.[10]

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[10] Which is not to say that this email does not present other concerns, most notably that CH did not retain litigation counsel for this Action until November 2020, when they retained Radulescu. *See* ECF No. 279 at 10:10–11:10; ECF No. 248 at 135 ("[A]fter we became aware of the – litigation or the situation, it took some time for us to find a trustworthy law firm here in the U.S."). The "DELAY and AVOID" email chain from early 2020 suggests that Radulescu was advising CH on this Action months earlier.

c. *Trial Conduct*

Plaintiffs next point to CH's attempts to use documents related to CH's withdrawn inequitable conduct claims. ECF No. 233 at 13–14; ECF No. 241 at 12–13. The Court excluded reference to those documents several times during trial but finds no malice of bad faith in Defendants' attempts to divine whether those documents could be used to support claims or defenses unrelated to inequitable conduct. Plaintiffs also identified in CH's exhibit list an exhibit that the Court had excluded—but CH quickly rectified that issue. ECF No. 233 at 13; ECF No. 241 at 12–13. Again, the Court will not attribute this mistake to malice.

3. Conclusion

Considering the totality of the circumstances, the Court finds that this case is not exceptional. Defendants committed missteps but they did not "present false testimony, or destroy documents like the cases reviewed and deemed to be exceptional by the Federal Circuit." *Core Wireless Licensing S.A.R.L. v. LG Elecs., Inc.*, No. 2:14-CV-00912-JRG, 2020 WL 1478396, at *3 (E.D. Tex. Mar. 26, 2020) (citing *SFA Sys., LLC v. Newegg Inc.*, 793 F.3d 1344, 1350–52 (Fed. Cir. 2015)). "What constitutes an exceptional case should not become part and parcel of losing a hard-fought and contentious trial." *Id.* at *4 (citing *Checkpoint Sys., Inc. v. All-Tag Sec. S.A.*, 858 F.3d 1371, 1376 (Fed. Cir. 2017)). The Court will not award Plaintiffs fees just because this Action was unnecessarily contentious and Defendants ultimately lost on all issues. And while Defendants may have conducted themselves in an unreasonable manner on certain issues and approached exceptional territory, the Court does not conclude this rendered the "overall" case exceptional. *See Intellectual Ventures I LLC v. Trend Micro Inc.*, 944 F.3d 1380, 1384 (Fed. Cir. 2019). For similar reasons, the Court denies Plaintiffs' request as to § 1927.

IV. PERMANENT INJUNCTION

Plaintiffs' Motion for a Permanent Injunction, ECF No. 234, is **DENIED**. Plaintiffs have failed to satisfy the irreparable injury factor, among others.

A. Legal Standard

District Courts may enter a permanent injunction to restrain a party from patent infringement "in accordance with the principles of equity to prevent the violation of any right secured by patent, on such terms as the court deems reasonable." 35 U.S.C. § 283. There are four findings the Court must make when deciding to issue an injunction: (1) that the plaintiff has suffered an irreparable injury; (2) that remedies available at law, such as monetary damages, are inadequate to compensate for the injury; (3) that, considering the balance of hardships between the parties, a remedy in equity is warranted; and (4) that the public interest would not be disserved by a permanent injunction. *eBay Inc. v. MercExchange, L.L.C.*, 547 U.S. 388, 391 (2006). "The movant must prove that it meets all four equitable factors[,] [a]nd it must do so on the merits of its particular case." *Nichia Corp. v. Everlight Ams., Inc.*, 855 F.3d 1328, 1341 (Fed. Cir. 2017) (citations omitted).

B. Discussion

To make a showing of irreparable injury supporting a permanent injunction, Super Lighting must show both that (1) it will suffer irreparable harm absent an injunction, and (2) a sufficiently strong causal nexus relates the alleged harm to the alleged infringement. *Apple Inc. v. Samsung Elecs. Co.*, 735 F.3d 1352, 1359–60 (Fed. Cir. 2013) (hereinafter *Apple III*). "[T]he causal nexus requirement is simply a way of distinguishing between irreparable harm caused by patent infringement and irreparable harm caused by otherwise lawful competition." *Id.* at 1361. Defendants take little issue with the proposition that Plaintiffs have suffered harm through competing with CH. Rather, Defendants claim there is no causal nexus relating that harm to patent infringement. The Court agrees.

1. <u>Irreparable Harm Absent an Injunction</u>

Plaintiffs' threshold premise is that Super Lighting and CH are direct competitors, which "weighs heavily in favor of a finding of irreparable injury." ECF No. 234 at 8 (first quoting *i4i Ltd. P'ship v. Microsoft Corp.*, 670 F. Supp. 2d 568, 599 (E.D. Tex. 2009); then citing *Douglas Dynamics, LLC v. Buyers Prods. Co.*, 717 F.3d 1336, 1345 (Fed. Cir. 2013); then citing *Broadcom Corp. v. Emulex Corp.*, 732 F.3d 1325, 1338 (Fed. Cir. 2013); and then citing *Novozymes A/S v. Genencor Int'l, Inc.*, 474 F. Supp. 2d 592, 612-13 (D. Del. 2007)). Defendants do not deny Plaintiffs' characterization of Super Lighting and CH as direct competitors. Plaintiffs go further, however, in describing CH as an "archrival" to Super Lighting, citing CH's hiring Jack Jiang away from Super Lighting, and Jack Jiang's subsequent hiring of Jun Yang away from Super Lighting. *Id.* at 9. Plaintiffs portray this activity, along with, for example, CH's possession of Super Lighting's confidential internal testing reports, as evidence of a "scheme to usurp Super Lighting's technology and take down Super Lighting's business." *Id.* They go as far as to allege that CH stole Super Lighting's technology and implemented it in its infringing products. *Id.* at 9–10.

Plaintiffs name the specific economic harms CH's infringement has inflicted upon Super Lighting: lost sales, lost profit margins, and lost market share. First, Super Lighting argues that it lost sales to CH, citing testimony from Super Lighting's own witnesses. ECF No. 234 at 10. Plaintiffs adduced evidence that Super Lighting made 84% its sales during the damages period to existing CH customers and CH made 89% its sales during that period to Super Lighting's existing customers. *Id.* At trial, CH's damages expert agreed that the parties "sell to the same types of customers and the same categories of customers over the entire damages period." *Id.* Super Lighting and CH initially agreed that Super Lighting's witnesses attributed those lost sales to CH's ability to undercut Super Lighting. *Id.* at 7 ("Multiple Super Lighting witnesses confirmed that they had lost sales to CH due to CH's predatory pricing. . . . And the reason CH could charge so little was plain: because CH was improperly using Super Lighting's inventions without being burdened by Super Lighting's cost for research and development."); *id.* at 10 ("CH was able to undercut Super Lighting's sales with lower prices."); ECF No. 246 at 3–4. Plaintiffs argued that CH had the pricing flexibility because it was not burdened with the cost of research and development (R&D). ECF No. 234 at 10. In opposition, CH contends that Plaintiffs have not provided any substantive analysis that "Defendants' prices are lower *because* their products incorporate the patented features." ECF No. 246 at 4. On that point, the Court agrees with Defendants.

In reply, Plaintiffs reversed position and argued that "CH and Super Lighting's products are comparably priced over the damages period." ECF No. 253 at 2. Plaintiffs further averred that because customers purchased comparably priced products from both Super Lighting and CH, "pricing is not the only demand drivers for customers." *Id.* at 2–3. The reply then retreated to Plaintiff's opening position: if CH's prices are lower, it is only because CH was not burdened with R&D costs. *Id.* at 3. This inconsistency regarding this predatory pricing point certainly does not help Plaintiffs surmount their burden further undermines Plaintiffs' "causal nexus" position. *See* ECF No. 279 at 58:19–59:23.

Second, Super Lighting argues that CH's pricing scheme resulted in a decline of Super Lighting's gross margins over time—from $0.61 per unit during the damages period to $0.41 per unit in 2021. ECF No. 234 at 10. Defendants contend that Plaintiffs offered no evidence that the presence of infringing features in the infringing products caused the margin erosion. ECF No. 246

at 5. Defendants cited testimony from its damages expert that he saw no evidence that the decrease in profit margin was attributable to CH's infringement. *Id.*

Third, Super Lighting also asserts that its market share decreased from 19% in 2018 to 11.7% in 2020. ECF No. 234 at 10. Plaintiffs contend that the loss (or potential loss) of sales and market share is "the very essence of irreparable harm." *Id.* (first citing *TEK Glob., S.R.L. v. Sealant Sys. Int'l*, 920 F.3d 777, 793 (Fed. Cir. 2019); then citing *Robert Bosch LLC v. Pylon Mfg. Corp.*, 659 F.3d 1142, 1151 (Fed. Cir. 2011); then citing *Purdue Pharma L.P. v. Boehringer Ingelheim GmbH*, 237 F.3d 1359, 1368 (Fed. Cir. 2001); and then citing *i4i*, 670 F. Supp. 2d at 600). Defendants assert that this reduction may be merely attributable to Defendants' lower prices. ECF No. 246 at 5. Yet, as the Court notes above, Plaintiffs credit those lower prices to CH's freeriding on Plaintiffs' innovation.

This Court follows *Apple IV* in holding "that competition between the patentee and the infringer, particularly direct competition, strongly militates toward a finding of irreparable harm." *Apple Inc. v. Samsung Elecs. Co.*, 809 F.3d 633, 653 (Fed. Cir. 2015) (hereinafter *Apple IV*). Plaintiffs and Defendants are clearly direct competitors and, as Plaintiffs suggest, maybe even archrivals. Given that, and the evidence of lost sales, lost profit margins, and lost market share, the Court is satisfied that competition with CH caused Plaintiffs irreparable harm. The Court must satisfy itself, however, that CH's infringing conduct, and not lawful competition, caused that harm. *Apple III*, 735 F.3d at 1361.

2. Causal Nexus

To show a causal nexus between the harm that Super Lighting has suffered and CH's infringement, Super Lighting must show "some connection between the patented feature and demand for [the infringer's] products." *Id.* at 1364. "The purpose of the causal nexus requirement is to establish the link between the infringement and the harm, to ensure that there is 'some connection' between the harm alleged and the infringing acts." *Apple IV*, 809 F.3d at 640. Super Lighting has failed to illuminate the causal nexus here.

Plaintiffs characterize the patented features as follows:

- The '140 patent's claimed feature is "shock protection circuitry." *See* ECF No. 234 at 4, 9. Tao Jiang, Super Lighting's CEO, and Aiming Xiong, head of R&D at Super Lighting, testified that this "prevents installers of LED tube lamps from being electrically shock[ed] and therefore improves product safety." *Id.* at 13 (first citing ECF No. 237 at 77:9–14 (testimony of Tao Jiang), then citing ECF No. 237 at 118:2–7 (testimony of Aiming Xiong)).
- The '125 patent's claimed feature is a "new concept of affixing the flexibility printed circuit ('FPC') on the inside surface of the lamp tube." *Id.* (citing ECF No. 237 at 69:2–3 (testimony of Tao Jiang)). Plaintiffs contend that this new design "enables wider light emission angles, offers sleeker appearance, and prevents electric shock." *Id.* (citing ECF No. 237 at 71:6–21 (testimony of Tao Jiang)).
- The '540 patent's claimed feature is an expansion upon "'the '125 invention based upon the improved relationship between the components, including the glass and glueable FPC' to produce better workmanship and more beautiful products." *Id.* (quoting ECF No. 237 at 76:3–9 (testimony of Tao Jiang)).

Plaintiffs then argue that there is "some connection" between these features and consumer demand sufficient to evidence a causal nexus. ECF No. 253 at 4 (quoting *Apple III*, 735 F.3d at 1364); ECF No. 234 at 13–14. In doing so, Plaintiffs almost exclusively refer to trial testimony discussing consumers' interest in safety features:

- Obert's CEO, Ryan Lu, testified, in response to a question about why customers prefer Obert tubes, that "it definitely may help the user a lot by take [sic] advantage of the safety feature." ECF No. 237 at 152:21–153:5. He continued, "It save [sic] a lot of the installation time, and it keep [sic] the installer safe at all costs." *Id.*
- Super Lighting's sales director, Barry Qin, testified that Plaintiffs' lamp product is "the safest one in the market currently." ECF No. 238 at 172:25–173:5.
- Jun Yang testified that customers "care" about the safety of LED lamps to the extent that CH Lighting "would need to obtain certifications related to safety, for example, the UL certification." ECF No. 237 at 205:19–23. And those certifications seemingly implicate measures to deal with electrical shocks. *Id.* at 205:24–206:3. (But, as CH Lighting notes, "Plaintiffs have never argued, and cannot argue, that practicing the '140 patent is necessary to obtain UL certification." ECF No. 246 at 8 n.3.)
- Jack Jiang testified that it was "absolutely correct" that the safety of LED tube lamps is an "important thing that customers care about." ECF No. 237 at 225:4–7.

The parties debate whether this evidence establishes a sufficient connection between the patented features and consumer demand, CH Lighting relying on *Apple III* and Plaintiffs relying on *Apple IV*. *See* ECF No. 246 at 7; ECF No. 253 at 4. In the former opinion, the plaintiff submitted evidence that ease-of-use was important to smartphone consumers but the lower court deemed that evidence "too general" where the patented feature—tap-to-zoom—was "very specific." *Apple, Inc. v. Samsung Elecs. Co.*, 909 F. Supp. 2d 1147, 1155 (N.D. Cal. 2012).

> A consumer may want a phone that is easy to use, but this does not establish that a tap-to-zoom feature, for example, or any given type of gesture, is a driver of consumer demand. Thus, Apple's evidence of a survey showing the importance of ease of use as a general matter . . . does not establish that infringement of any of Apple's *patents* caused any harm that Apple has experienced. To establish

> the required nexus, Apple must make a showing specific to each patented feature. Many factors go into making a product easy to use, but the features for which Apple is asserting patent protection are very specific.

Id. The Federal Circuit agreed. *See Apple III*, 735 F.3d at 1367 ("The district court was thus correct in concluding that Apple's evidence of ease of use, although relevant, was too general, standing alone, to establish a causal nexus."). The evidence that consumers care about shock protection is, in CH's opinion, too general here where the '140 patent, for example, is directed to a specific shock protection circuit. *See* ECF No. 246 at 7–8.

In reply, Plaintiffs cling to *Apple IV*'s statement that the "causal nexus" inquiry is a "flexible one." ECF No. 253 at 1; ECF No. 279 at 33:3–6. The *Apple IV* court held that a plaintiff could make out a causal nexus with "evidence that a patented feature is one of several features that cause consumers to make their purchasing decisions." *Apple IV*, 809 F.3d at 642 (quoting *Apple III*, 735 F.3d at 1364). Plaintiffs allege the "the prevention of electric shocks" is just such a feature. ECF No. 253 at 4. Yet that identifies the patented feature at a higher level of generality than Plaintiffs characterize it elsewhere. *See, e.g.*, ECF No. 234 at 4 (describing how circuitry embodies the '140 patent).

Apple III cautions against such overgeneralizations. Again, the *Apple III* opinion affirmed that a plaintiff must show that the patented feature *in particular* drives demand for the accused product. The *Apple IV* opinion, on the other hand, merely clarified that establishing a causal nexus does not require the plaintiff to prove that the patented feature is the exclusive driver of demand for the accused product; a showing that the patented feature "impacts customers' purchasing decisions" will suffice. 809 F.3d at 641. That customers care about safety and shock protection generally is, as CH Lighting concedes, "uncontroversial." *See* ECF No. 246 at 8 & n.3. CH Lighting's challenge, rather, turns on the absence of record evidence showing that customers care about shock protection *particular to the patented features*. The Court finds this argument persuasive. Just as the *Apple III* plaintiffs failed to adduce evidence specific to the tap-to-zoom feature, Plaintiffs have not cited evidence of customer demand specific to that degree or category of shock protection attributable to the '140 patent's claimed circuit.[11]

Plaintiffs, of course, disagree. Their most compelling evidence is Mr. Lu's testimony, elicited in response to a question about why customers prefer Obert lamp tubes, that it "may help the end user a lot by take advantage of the safety feature and the double-ended Type B tubes." ECF No. 253 at 4–5. Unless the Court construes Mr. Lu's recitation of "the safety feature" as a reference to the claimed circuitry of the '140 patent, this testimony is too general. Plaintiffs' counsel did not seek to clarify what Mr. Lu meant by "safety feature." And immediate context offers little support; this answer was not elicited amidst a conversation about shock protection circuitry. Adopting such a construction would treat Plaintiffs, the side bearing the burden here, too generously. Even if it ventured to accept the construction, the Court is dubious of the reliability of this testimony because it is self-serving—Mr. Lu is Obert's CEO—and unsupported by other admitted evidence. *See Rest. Law Ctr. v. United States DOL*, No. 1:21-CV-1106-RP, 2022 U.S. Dist. LEXIS 30368, at *12 (W.D. Tex. Feb. 22, 2022) ("The Court declines to rely on such speculative and self-serving testimony to make a finding of irreparable harm."); *see* ECF No. 279 at 60:25–61:6 (criticizing the testimony Plaintiffs rely on because it comes from self-interested, non-expert witnesses).

[11] As opposed to shock protection from a noninfringing component. For example, Plaintiffs' technical expert testified that prior art LED tube lamps with UL certification would likely have had shock protection features. ECF No. 237 at 195:1–7.

Plaintiffs focused on the ’140 patented feature, preserving little space to elaborate on the causal nexus relevant to the ’125 and ’540 patented features. What evidence Plaintiffs offer fails show a casual nexus.

For the foregoing reasons, the Court concludes that Plaintiffs have not established a causal nexus or, it follows, any irreparable injury justifying a permanent injunction. In addition, Plaintiffs have tied the next two *eBay* factors to the existence of an irreparable injury, so Plaintiffs have likewise failed to satisfy those factors. *See* ECF No. 234 at 15 (“The inadequacy of remedies at law is closely related to irreparable harm, and the two can be analyzed together.”); *id.* at 16 (relying on the harm to Super Lighting). Failing these, Plaintiffs have not shown their entitlement to a permanent injunction.

V. PRE- AND POST-JUDGMENT INTERESTS AND BILL OF COSTS

Briefing on Plaintiffs’ Motion for Entry of Judgment, ECF No. 242, included requests for prejudgment and post-judgment. *See* ECF No. 242 at 4. The Court will grant both.

A damages award should provide “complete compensation,” *Gen. Motors Corp. v. Devex Corp.*, 461 U.S. 648, 655 (1983), including “a reasonable royalty for the use made of the invention by the infringer, together with interest and costs.” 35 U.S.C. § 284. “The purpose of prejudgment interest is to place the patentee in as good a position as he would have been had the infringer paid a reasonable royalty rather than infringe.” *SSL Servs., LLC v. Citrix Sys., Inc.*, 769 F.3d 1073, 1094 (Fed. Cir. 2014). “The award of pre-judgment interest is the rule, not the exception.” *Energy Transp. Grp., Inc. v. William Demant Holding A/S*, 697 F.3d 1342, 1358 (Fed. Cir. 2012). But Section 284 does not “requir[e] the award of prejudgment interest whenever infringement is found.” *Devex*, 461 U.S. at 655–56. The Court sees no reason to deviate from the rule here—and Defendants give it none. But, to be clear, prejudgment interest should only be awarded on the Jury’s damages award—not on any enhancement thereto. *See Underwater Devices Inc. v.*

Morrison-Knudsen Co., 717 F.2d 1380, 1389 (Fed. Cir. 1983), *overruled on other grounds*, *In re Seagate Tech., LLC*, 497 F.3d 1360 (Fed. Cir. 2007) ("[W]e hold that prejudgment interest can only be applied to the primary or actual damage portion and not to the punitive or enhanced portion."); *see also Beatrice Foods Co. v. New England Printing & Lithographing Co.*, 923 F.2d 1576, 1580 (Fed. Cir. 1991) (discussing *Underwater Devices* holding).

The parties also vigorously dispute what interest rate should be applied. "The rate of prejudgment interest and whether it should be compounded or uncompounded are matters left largely to the discretion of the district court." *Bio-Rad Labs., Inc. v. Nicolet Instrument Corp.*, 807 F.2d 964, 969 (Fed. Cir. 1986). When exercising that discretion, the Court recognizes the purpose of prejudgment interest is to compensate the patent owner for infringement. *Imperium IP Holdings (Cayman), Ltd. v. Samsung Elecs. Co.*, 757 Fed. Appx. 974, 2017 WL 1716589, at *4 (E.D. Tex. 2017). The Court will not adopt of the prime rate, finding that "[t]he T-Bill rate is well-accepted in federal courts and is a reasonable method of placing [Plaintiffs] in a position of where [they] would have been had there been no infringement by [Defendants]." *VLSI Tech. LLC v. Intel Corp.*, No. 6:21-CV-57-ADA, 2022 U.S. Dist. LEXIS 83985, at *7 (W.D. Tex. Apr. 21, 2022). "It is well within the Court's discretion to apply the T-Bill rate." *Id.* (citing *Verinata Health, Inc. v. Ariosa Diagnostics, Inc.*, 809 F. App'x 965, 977 (Fed. Cir. 2020)). So, the rate applied should be the average T-Bill rate, compounded annually, from the issue date of the '140 patent, which the Jury heard was the date of the hypothetical negotiation, to the date of the Court's forthcoming final judgment. *See* ECF No. 226 at 28.

The parties do not dispute that 28 U.S.C. § 1961 controls what interest rate should be applied for post-judgment interest. *Compare* ECF No. 249 at 7, *with* ECF No. 260 at 2. Accordingly, the Court awards post-judgment interest at the statutory rate, compounded annually, starting from the date of the Court's forthcoming final judgment until the date of payment. Post-judgment interest will apply to the total award including damages found by the jury, prejudgment interest applied to that award, and the enhanced damages award. *See Ericsson Inc. v. TCL Commc'n Tech. Holdings, Ltd.*, No. 2:15-CV-00011-RSP, 2018 WL 2149736, at *14 (E.D. Tex. May 10, 2018), *vacated on other grounds*, 955 F.3d 1317 (Fed. Cir. 2020).

As a final matter, the briefing on the Motion for Entry of Judgment also included disputes as to Plaintiffs' Bill of Costs. *See* ECF No. 268. The parties subsequently came to an agreement on that Bill, ECF No. 278, and the Court will enter that agreed Bill of Costs promptly after entering judgment.

VI. CONCLUSION

It is therefore **ORDERED**

- Plaintiffs' Motion for Enhancement of Damages Under 35 U.S.C. § 284, ECF No. 233, is **GRANTED-IN-PART**;
- Plaintiffs' Motion for Exceptional Case and Attorney Fees, ECF No. 241, is **DENIED**;
- Plaintiffs' Motion for Permanent Injunction, ECF No. 234, is **DENIED**.

It is further **ORDERED** that Plaintiffs' Motion for Entry of Judgment, ECF No. 242, is **HELD IN ABEYANCE** pending the parties' resolution of the precise dollar amount of enhancement the Court has ordered. The parties are instructed to: meet and confer regarding the dollar amount of enhancement the Court ordered above; and jointly draft a proposed order of judgment consistent with the rulings above, to be sent to the Court by July 28, 2022, on which date the Court will enter judgment.

SIGNED this 16th day of August, 2022.

ALAN D ALBRIGHT
UNITED STATES DISTRICT JUDGE

IN THE UNITED STATES DISTRICT COURT
FOR THE WESTERN DISTRICT OF TEXAS
WACO DIVISION

JIAXING SUPER LIGHTING ELECTRIC APPLIANCE CO., LTD. AND OBERT, INC., Plaintiffs, v. **CH LIGHTING TECHNOLOGY CO., LTD., ELLIOTT ELECTRIC SUPPLY INC. AND SHAOXING RUISING LIGHTING CO., LTD.,** Defendants.	§ § § § § § § § § § §	CASE NO. 6:20-CV-00018-ADA JURY TRIAL DEMANDED

AMENDED MEMORANDUM OPINION & ORDER

Came on for consideration this date are Plaintiffs' Motion for Supplemental Damages, Ongoing Royalty and Enhancement of Post-Verdict Damages, ECF No. 287; Defendants' Motion for Judgment as a Matter of Law, ECF No. 291; and Defendants' Motion for New Trial, ECF No. 292. The Court presided over a four-day jury trial from November 1, 2021 to November 4, 2021. *See* ECF Nos. 237–40. At the end, the Jury found Defendants CH Lighting Technology Co., Ltd. ("CH Lighting" or "CH"), Elliott Electric Supply Inc. ("Elliott"), and Shaoxing Ruising Lighting Co. Ltd. ("Ruising") (collectively, "Defendants") to have willfully infringed claims of three patents of Plaintiffs Jiaxing Super Lighting Electric Appliance Co., Ltd. ("Super Lighting") and Obert, Inc. ("Obert") (collectively, "Plaintiffs" or "Super Lighting"). ECF No. 230.

For the reasons set forth below, the Court will deny Defendants' motions for judgment as a matter of law and new trial, and grant-in-part Plaintiffs' motion for supplemental damages, ongoing royalty and enhancement of post-verdict damages.

I. BACKGROUND

On January 10, 2020, Plaintiffs initiated this Action by filing a complaint alleging that Defendants infringe certain U.S. patents. ECF No. 1 (the "Complaint"). On March 16, 2020, Plaintiffs filed an amended complaint alleging infringement of U.S. Patent Nos. 10,295,125 (the "'125 patent"), 10,342,078, 10,352,540 (the "'540 patent"), and 10,426,003, 9,939,140 (the "'140 patent"), 10,378,700, 10,448,479, and 10,560,989. ECF No. 21 (the "FAC"). CH answered on December 3, 2020. ECF No. 67. The Plaintiffs' patents and Defendants' accused products are directed to light-emitting diode (LED) tube lamps and features thereof. Super Lighting is a Chinese corporation and Obert is its North American affiliate. ECF No. 21 ¶¶ 1, 2. CH and Ruising are also Chinese corporations and Elliott is a customer of some sort based out of Texas. *See, e.g.*, ECF No. 237 at 40:12–20, 46:18–22, 78:9–79:10. Ruising is the subsidiary of CH charged with selling CH products.[1] *See id.* at 78:9–79:10. Super Lighting and CH are rivals in the tube lamp space. Ruising is owned at least by Caiying Gan, CEO of CH, and Qingbo "Jack" Jiang, who also runs Ruising. *See id.* at 78:9–79:10. Before he was at Ruising, Jack Jiang was a Super Lighting employee. He left in 2014 to join Ruising and later convinced Jun Yang, technical assistant and secretary to Super Lighting's CEO and founder, to join him there. *See id.* at 82:15–83:7. According to Super Lighting's CEO, Mr. Yang had access to Super Lighting's most confidential, technical documents. *Id.* at 82:24–83:5. Mr. Yang is now a product manager at Ruising. *See id.* at 204:1–9.

On October 6, 2021, the Court held a pretrial conference in this Action. *See* ECF Nos. 190, 191. Trial commenced on November 1, 2021. *See* ECF No. 216. At trial, Plaintiffs had narrowed their case such that they only asserted infringement of claim 1 of the '125 patent, claims 1, 4, 5, 24, 28, and 31 of the '140 patent, and claims 13 and 14 of the '540 patent. Shortly before trial,

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[1] When the Court refers to CH it is oftentimes referring to CH and Ruising collectively.

Defendants stipulated to infringement for all but one accused product—Defendants argued to the Jury that the LT2600 integrated circuit did not infringe the asserted claims of the '140 patent. Defendants also presented an invalidity case against the '125, '140, and '540 patents (the "Asserted Patents") to the Jury. *Id.* at 8–9.

On the third day of trial, the Court granted a pre-verdict motion for judgment as a matter of law (JMOL) under Federal Rule of Civil Procedure 50(a) on the issue of the invalidity relating to the '125 patent and the '540 patents. ECF No. 239 at 47:8–53:11. The Court held that there was not a legally sufficient evidentiary basis upon which a reasonable jury could have concluded that: claim 1 of the '125 patent was invalid based on any of Defendants' three prior-art grounds against that patent; or the asserted claims of the '540 patent were invalid based on one of Defendants' two prior-art grounds against that patent. *Id.* Defendants based these deficient prior-art grounds on system prior art—physical lighting tubes—that Defendants failed to introduce into evidence before evidence closed. *See id.*

On November 4, 2021, the Jury rendered a unanimous verdict, finding that Defendants infringed all Asserted Claims and that Defendants failed to prove that any Asserted Claim was invalid. ECF No. 230. The Jury awarded damages in the amount of $13,872,872 from CH and Ruising and $298,454 from Elliott and further found that CH and Ruising willfully infringed.

On November 24, 2021, Plaintiffs moved for enhanced damages and a permanent injunction. ECF Nos. 233, 234. On December 2, 2021, Plaintiffs moved for attorneys' fees and entry of judgment. ECF Nos. 241, 242. On July 21, 2022, the Court granted-in-part Plaintiff's Motion for Enhancement of Damages under 35 U.S.C. § 284 and denied Plaintiffs' Motion for exceptional case, attorney fees and for a permanent injunction. ECF No. 281.

On August 19, 2022, Plaintiffs filed a motion for supplemental damages, ongoing royalty and enhancement of post-verdict damages. ECF No. 287. And on August 26, 2022, Defendants filed a motion for judgment as a matter of law and a motion for a new trial. ECF Nos. 291–92. The parties briefing on these post-trial motions was completed on September 16, 2022. *See* ECF Nos. 303, 305, 306. These motions are now ripe for judgment.

II. MOTION FOR JUDGMENT AS A MATTER OF LAW

A. Legal Standard

A court may grant JMOL against a prevailing party only if a reasonable jury would not have a legally sufficient evidentiary basis to find for the non-moving party on that issue. Fed. R. Civ. P. 50(a)(1). In deciding a renewed JMOL motion, a "court must draw all reasonable inferences in favor of the nonmoving party, and it may not make credibility determinations or weigh the evidence." *Taylor-Travis v. Jackson State Univ.*, 984 F.3d 1107, 1112 (5th Cir. 2021). The court must disregard all evidence favorable to the moving party that the jury is not required to believe. *Id*. This is because "[c]redibility determinations, the weighing of the evidence, and the drawing of legitimate inferences from the facts are jury functions, not those of a judge." *Wellogix, Inc. v. Accenture, L.L.P.*, 716 F.3d 867, 874 (5th Cir. 2013).

Courts grant JMOL for the party bearing the burden of proof only in extreme cases, when the party bearing the burden of proof has established its case by evidence that the jury would not be at liberty to disbelieve, and the only reasonable conclusion is in its favor. *Mentor H/S, Inc. v. Medical Device All., Inc.*, 244 F.3d 1365, 1375 (Fed. Cir. 2001). JMOL is inappropriate if the record evidence is such that reasonable and fair-minded men in the exercise of impartial judgment might reach different conclusions. *Laxton v. Gap Inc.*, 333 F.3d 572, 579 (5th Cir. 2003).

A jury verdict must stand unless there is a lack of substantial evidence, in the light most favorable to the successful party, to support the verdict. *Am. Home Assur. Co. v. United Space All., LLC*, 378 F.3d 482, 487 (5th Cir. 2004). Substantial evidence is more than a scintilla, but less than a preponderance. *Nichols v. Reliance Standard Life Ins. Co.*, 924 F.3d 802, 808 (5th Cir. 2019). Thus, JMOL must be denied if a jury's verdict is supported by legally sufficient evidence that amounts to more than a mere scintilla. *Laxton*, 333 F.3d at 585.

B. Discussion

Defendants move for judgment as a matter of law under Rule 50(b) for three reasons: (1) that there is not substantial evidence to support the Jury's validity findings; (2) that there is not substantial evidence to support the Jury's infringement findings; and (3) and that there is not substantial evidence to support a finding of willfulness. *See, generally*, ECF No. 291. The Court will address each of these in turn below. As a preliminary matter, however, the Court will address the Plaintiffs' arguments that because this is a renewed motion for judgment as a matter of law under Rule 50(b), the Defendants are strictly limited to those arguments that presented under their original Rule 50(a) motion.

Although Defendants cite only the language of Rule 50(a), their motion is actually a ***renewed*** motion for JMOL under Rule 50(b). A party forfeits the right to move under Rule 50(b) by failing to move first under Rule 50(a), and issues raised for the first time in a Rule 50(b) motion cannot be considered. *i4i Ltd. P'ship v. Microsoft Corp.*, 598 F.3d 831, 845 (Fed. Cir. 2010), *aff'd*, 564 U.S. 91 (2011); *see also VLSI Tech. LLC v. Intel Corp.*, No. 6:21-CV-057-ADA, 2022 WL 1477725, at *7 (W.D. Tex. May 10, 2022).

Plaintiffs primarily raise two issues of the impropriety of Defendants' ***renewed*** motion for JMOL under Rule 50(b).

First, Plaintiffs argue that as to infringement and willful infringement, "Defendants failed to cite any specific basis why it was entitled to JMOL in their Rule 50(a) motion . . . . [n]or did Defendants raise any of the specific arguments in their Rule 50(a) motion that they are now making." ECF No. 299 at 4. According to Plaintiffs, "[t]he transcript portions cited by Defendants in their brief did not form any basis to request a Rule 50(b) motion on issues such as infringement and willfulness." *Id.* (citing ECF No. 291 at 3, which cites "Trial Tr. Day 3" at 67:22–71:10 (requesting JMOL on invalidity and damages)). Moreover, according to Plaintiffs, "regarding non-infringement, Defendants now rely ([ECF No. 291] at 15-17) almost entirely on Dr. Zane's testimony. But Defendants did not raise any argument in any pre-verdict JMOL based on the purportedly missing elements identified by Dr. Zane." *Id.* In their response brief, Plaintiffs preemptively respond to Defendants' reliance on the liberal interpretation of rule 50(a) in the Fifth Circuit. *Id.* Plaintiffs argue that even under the liberal Fifth Circuit standard, Defendants have not placed Plaintiffs or the Court on notice of any specific claim element that Plaintiffs supposedly failed to prove.

In reply, Defendants contend that "CH specifically moved for JMOL of non-infringement, citing 'insufficient evidence to establish . . . that Defendants infringe any claim of' the '140 patent." ECF No. 305 at 9 (citing Day 2 Tr. 100:14–24). According to Defendants, [t]hat motion preserves CH's arguments." *Id.* Defendants rely on *Navigant Consulting, Inc. v. Wilkinson*, 508 F.3d 277, 288 (5th Cir. 2007), which held that "Rule 50(b) is construed liberally, and [courts] may excuse 'technical noncompliance' when the purposes of the rule are satisfied." *Id.* Defendants also rebut Plaintiffs' allegation that Defendants failed to preserve its Rule 50(b) motion because Defendants argue that "CH specifically moved for JMOL because the evidence was 'insufficient . . . to establish that Defendants willfully infringed any asserted claim of any asserted patent.'" *Id.* at 10 (citing Day 2 Tr. 100:25–101:11).

The Court will address any alleged new non-infringement or willfulness argument as it comes up below.

Second, Plaintiffs argue that "at least with respect to the product prior art, Defendants' motion for JMOL of invalidity is nonsensical because the Court granted Plaintiffs' JMOL on that issue before Plaintiffs' rebuttal case." *Id.* The Plaintiffs rely on Rule 50, which states that that JMOL may be granted only "if a party has been fully heard on an issue during a jury trial." Because the Court had already granted JMOL, Plaintiffs' validity expert, Dr. Phinney, did not address the '125 Patent or the product prior art. *Id.* (citing Trial Tr. Day 2 at 64:3–19, 82:14–25).

In reply, Defendants argue only even though Plaintiffs did not have the opportunity to present their case regarding the '125 Patent, "they admit that their proof would have mirrored the insufficient evidence they offered on 'the same element' of the '540 patent." ECF No. 305 at 4. According to Defendants. "[a] vague promise of 'more of the same' should not defeat JMOL." *Id.* The defendants do not address the product prior art arguments.

The Court agrees with the Plaintiffs and finds that the Defendants have waived these arguments regarding the '125 Patent or the product prior art. *VLSI*, 2022 WL 1477725, at *7 (new argument waived by failure to raise in pretrial JMOL even though sufficiency of proof of element was raised). Accordingly, Defendants' motion for JMOL as to the validity of the '125 Patent or the product prior art is hereby denied.

i. Substantial Evidence Supports the Jury's Validity Findings for the '140 and '540 Patents

At trial, Defendants asserted that Claims 13 and 14 of the '540 patent and Claims 1, 4, and 24, and dependent claims 4, 28, and 31 of the '140 patent were invalid. The Jury found that

Defendants did not prove by clear and convincing evidence that those claims of the ’540 patent ’140 patent were invalid. ECF No. 230. Defendants argue, however, that this Court should enter JMOL of invalidity because “CH’s proof on invalidity showed how every purported advance was apparent in the prior art . . . [and] Plaintiffs failed to identify any inventive insight and repeatedly contradicted the plain language of both the patents and prior art.” ECF No. 305 at 8.

1. Substantial evidence supports the Jury’s Validity Findings for the ’540 Patent

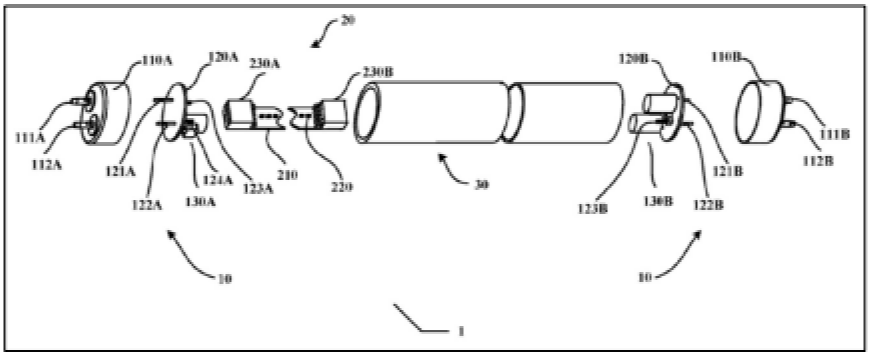
Defendants argue that the prior art renders the asserted claims of the ’540 Patent invalid because “[t]wo separate sets of prior art references make that clear: (1) U.S. Patent Nos. 9,970,640 B2 (“Zhao”) and 8,360,599 B2 (“Ivey II”); and (2) the MaxLite G Series L18T8DF440-G.” ECF No. 291 at 4.

a. Zhao and Ivey do not render Claim 13 obvious

Substantial evidence supported the Jury’s finding that Defendants failed to prove invalidity of claims 13 and 14 of the ’540 Patent by clear and convincing evidence. Defendants argue that Plaintiffs identified only two putative departures from prior-art, conventional LEDs: (1) an LED strip disposed on the “inner circumferential surface” of the tube; and (2) a “diffusion film” “disposed on” the lamp tube. ECF No. 291 at 6. Defendants contend that Zhao and Ivey render claim 13 obvious because they disclose, teach, or suggest these very same two differences that Plaintiffs allegedly identified as the difference between the claimed invention and the prior art. *See id*.

The Court disagrees with the Defendants. First, the Jury could have reasonably credited Dr. Phinney’s testimony and found that Defendants failed to prove an LED strip disposed on the “inner circumferential surface” of a lamp tube. *MobileMedia Ideas LLC v. Apple Inc.*, 780 F.3d 1159, 1168 (Fed. Cir. 2015) (citing *Kinetic Concepts, Inc. v. Smith & Nephew, Inc.*, 688 F.3d

1342, 1362 (Fed. Cir. 2012) ("In light of the jury's determination that [Defendant] failed to prove obviousness, we must infer that the jury found [Plaintiff's] experts to be credible and persuasive on this point")). For this element, Defendants relied on a single figure (Fig. 4, below) from the Zhao reference (ECF No. 296-25, DTX-60), and the corresponding text:



Day 2 Tr. at 303:3–9. As Dr. Phinney explained, the figure does not show how the parts fit together, and therefore does not teach a person of ordinary skill in the art that the LED strip is "disposed on the inner circumferential surface" as claimed. Day 3 Tr. at 11:4–10. Likewise, the corresponding text in Zhao merely indicates that the light strip is "inside" the tube. *Id.* at 11:13–24; ECF No. 296-25 at 4:16–17, 8:35–41.) Defendants do not explain why a reasonable Jury could have not credited it.

Moreover, at trial, Defendants failed to present a credible case of their own on this element. Defendants' expert offered only six lines of testimony on the issue. (Day 2 Tr. at 303:4–9.) Nothing in his testimony explained why a skilled artisan would infer that the light strip was disposed on an inner circumferential surface either from the figure or the cited portions of the specification teaching that the light strip was merely "inside" the tube. The Jury certainly was not required to credit Dr. Lebby's testimony over the more detailed explanation from Dr. Phinney.

In a possible attempt to reconcile the Jury's recognition of the apparent inadequacy of Dr. Lebby's trial testimony, Defendants raise two, completely new arguments in their motion: (1) that Zhao "shows nothing between the LED strip and the tube's 'inner circumferential surface,'" and (2) that "common sense would inform skilled artisans that disposing the strip directly on the tube was one option." ECF No. 291 at 5. Raised for the first time post-trial, both arguments are procedurally improper. *See Erfindergemeinschaft UroPep GbR v. Eli Lilly & Co.*, 276 F. Supp. 3d 629, 653 (E.D. Tex. 2017), *aff'd*, 739 F. App'x 643 (Fed. Cir. 2018).

b. MaxLite G Series does not render claim 13 obvious

Defendants asserted the same MaxLite tube against the '540 Patent as they did against the '125 Patent, and their case failed on pre-verdict JMOL for the same reasons. Trial Tr. Day 3 at 52:23–53:9. For the '540 Patent, Defendants have nothing but the same conclusory assertions that the MaxLite tube was prior art, ECF No. 291 at 6 (citing Trial Tr. Day 2 at 291:10–14)), and that it satisfied the requirement of a light strip disposed on the tube's "inner circumferential surface." ECF No. 291 at 6 (citing Trial Tr. Day 2 at 296:7–19). The Court agrees with Plaintiffs that Defendants' JMOL motion as to the MaxLite tube fails for the same reasons with respect to the '540 Patent that it does for the '125 Patent and that substantial evidence supported the Jury's determination that the MaxLite G Series does not render claim 13 obvious.

c. Neither the MaxLite lamp nor the Zhao reference render Claim 14 obvious

Defendants contend that dependent Claim 14 is rendered obvious in view of the MaxLite lamp or in view of the Zaho reference. ECF No. 291 at 7. Because the Court finds that substantial evidence supports the Jury's verdict that Claim 13 is not rendered obvious, the Court finds that substantial evidence also supports the Jury's verdict that Claim 14 is not obvious.

2. Substantial evidence supports the Jury's Validity Findings for the '140 Patent

Defendants assert that—contrary to the Jury's verdict—all asserted claims of the '140 Patent are rendered obvious in view of prior art references. ECF No. 291 at 10–15. Plaintiffs respond that "[a] reasonable jury could, and did, conclude that none of Defendants' references contained the claimed 'pulse generating circuit' that controls the switch that keeps the lights on, or turns them off." ECF No. 299 at 17. The Court will address each of their arguments in turn below.

a. Substantial evidence supports the Jury's finding that Claim 1 is not invalid in view of Ono

Defendants first argue that Claim 1 was anticipated by International Patent Application WO 2012/066822 ("Ono"). ECF No. 291 at 10. Claims 1 and 4 both recite a circuit that attempts to avoid unintended shocks by engaging the main circuit only when the LED lamp is properly installed. At trial, Plaintiffs' expert conceded that Ono uses pulses to detect whether installation is proper and, if it is, to turn on the light. Day 3 Tr. 90:23–91:2. But he argued that Claim 1 requires the opposite order of operations: It "goes right ahead and turns on the light first and then determines if there's a proper installation." *Id.* at 91:1–5. Defendants contend that Plaintiffs' expert "cited no language in the '140 Patent for that conclusion." ECF No. 291 at 11. According to Defendants, "[n]othing in the claim requires turning the lamp on before detecting proper installation." *Id.*

Plaintiffs argue that Ono does not anticipate Claim 1 because Ono operated in what Dr. Phinney explained was the "old way," by checking the power line to see if the light switch could be turned on in the first place. ECF 299 at 17. According to Plaintiffs, "[t]hat way was different from the claimed invention, which turns the light on before deciding whether it should stay on or be turned off." *Id.* The Court agrees with the Plaintiffs. At trial, Dr. Zane tried to equate Ono with the ’140 Patent by arguing that (1) the “pulse generating circuit generates a pulse and injects a signal … into the power loop,” (Day 2 Tr. at 197:4–5), and (2) “the detection determining circuit” then makes a “decision [that] goes directly to turn the switch on or off.” (*Id.* at 197:9–21.) But the Jury was free to weigh the credibility of the two experts and adopt Dr. Phinney’s description of Ono over Dr. Zane’s and find that Ono did not anticipate. *MobileMedia Ideas*, 780 F.3d at 1168. There is substantial evidence to support the Jury’s verdict here. *See* JTX-1 at 59:5–7 (stating the pulse generator controls the LEDs to turn on and off); *see also id.* at 59:18–20 (stating the detection circuit controls the switch to keep the LEDs on).

b. Substantial Evidence Supports the Jury’s finding that Claims 1, 4, 5, 24, 28, And 31 Are Not obvious Over Ivey I

Defendants also argue that the Jury lacked substantial evidence to find that claims 1, 4, 5, 24, 28, and 31 are not obvious over Ivey I. ECF No. 291 at 10. Yet because Defendants failed to move for JMOL on Ivey I against ’140 Patent claim 1, their renewed JMOL as to that claim has been forfeited. *See* Trial Tr. Day 3 at 68:1–70:11.

As to the remaining claims, the Court finds that Ivey 1 lacks two critical elements that a reasonable Jury could have found did not render these claims obvious.

First, it has the same defect as Ono—it lacks the required “pulse generating circuit” that controls the same switch that turns the lights on and off and represents the “old way” of doing things. Dr. Phinney explained that Ivey I’s alleged “pulse generator” did not control the switch for the LEDs but was instead an oscillator to switch a different element (test load). Trial Tr. Day 3 at 94:17–25. This switch for the test load ECF No. 296-21, DTX-65, FIG. 3, Element 135 does not control the switch that turns the LEDs on and off. Trial Tr. Day 3 at 94:17–95:12. Instead, Ivey I's light switch is elsewhere (DTX-65, FIG. 3, Element 175), and relied on different circuitry and control logic. Trial Tr. Day 3 at 95:17–21.

Second, and more simply, Ivey I is not even a "tube lamp." Ivey I taught only "an 'LED-based light' with a 'first connection point' and a 'second connection point.'" ECF No. 291 at 12 (citing DTX-65 ¶ 37) Defendants' expert did not argue that Ivey I taught a tube, just that a skilled artisan would "think of" a tube as an "example." Trial Tr. Day 2 at 213:13–15. And a reasonable Jury could have agreed with Dr. Phinney, who explained that Ivey itself did not teach or suggest a tube. Trial Tr. Day 3 at 92:23–93:1. Because the Jury could have reasonably sided with Dr. Phinney on either missing element, JMOL is unwarranted.

But Defendants and Dr. Zane further failed to demonstrate that Ivey I contains the required "detection result latching circuit" of Claims 4, 5, 24, 28, and 31. As argued by the Plaintiffs, Defendants have not provided sufficient evidence that "the alleged latching circuit outputs a 'high logic value when either the stored detected result or the pulse signal output terminal … has a high logic values' required by the claims." ECF No. 299 at 18–19.

In short, the Court finds that substantial evidence supports the Jury's finding that claims 1, 4, 5, 24, 28, and 31 are not obvious over Ivey I.

c. Substantial Evidence Supports the Jury's Finding That Claims 1, 4, 5, 24, 28, and 31 Are Not Obvious Over Ivey 1 In View of Sadwick

Similarly, the Court also finds that Defendants' arguments that the asserted claims are obvious over Ivey 1 in view of international patent application No. WO 2015/066566 ("Sadwick") to be unconvincing. Defendants attempt to fix Ivey I's shortcomings by combining it with Sadwick, a reference cited by the Examiner during prosecution. ECF No. 291 at 13. Specifically, Defendants argue that Sadwick makes up for any deficiency of Ivey I "[b]ecause

Sadwick discloses using a pulse to turn on the load switch, *id.* ¶ 83, skilled artisans would have understood pulses were one method for ensuring that the latch circuit turned power back on when "the hazard fault condition had cleared." *Id.* at 14.

As a preliminary matter, the Court finds that because Defendants failed to move for JMOL on Ivey I against '140 Patent claim 1, their renewed JMOL as to that claim has been forfeited. *See* Trial Tr. Day 3 at 68:1–70:11. Therefore, the Court considers the Defendants' arguments regarding combining the Ivey I and Sadwick references for the remaining asserted claims.

In the primary, Plaintiffs argue that Defendants' conclusory modification to combine Ivey I and Sadwick was presented to the Jury and Defendants failed to convince the Jury that a POSITA would have had any motivation or reasoning to modify Ivey I's circuit to do so. ECF No. 299 at 19 (citing *Arctic Cat Inc. v. Bombardier Recreational Prod. Inc.*, 876 F.3d 1350, 1359 (Fed. Cir. 2017) (it is a "fact question [] [regarding] whether one of ordinary skill in the art had a motivation to combine the prior art to achieve the claimed combination")).

The Court agrees. At trial, Dr. Phinney explained that Dr. Zane's modifications to Ivey I's structure were significant, and that the art itself presented no motivation to make those modifications. Trial Tr. Day 3 at 100:1–102:15, 104:13–106:20. A reasonable Jury could have concluded that Defendants had not met their burden on motivation to combine in light of the expert testimony.

d. Secondary considerations

Because the Court finds that substantial evidence supports the Jury's verdict that none of the asserted claims are invalid, the Court need not reach the Defendants arguments regarding secondary considerations.

ii. Substantial Evidence Supports the Jury's Infringement Findings for the '140 Patent

The Jury found that the accused devices using the LT2600 and the LT2600G chips infringe the '140 patent.[2] Defendants seek a JMOL on these findings. Defendants argue two reasons why this JMOL on noninfringement should be granted.[3] *First*, Defendants argue that the LT2600's "patented grid impedance monitoring algorithm" is different from the '140 Patent because it "detect[s] proper installation [of a tube lamp] based on grid impedance, rather than voltage alone." ECF No. 291 at 16. Plaintiffs respond that "the claims say nothing about what electrical property needs to be measured to provide the 'sampling signal' to determine proper installation." ECF No. 299 at 14.

The '140 Patent itself explains that the detection circuitry may detect when one end of a tube lamp is connected to a "high impedance, such as a person." *Id.* Critically, Plaintiffs argue that Dr. Zane admitted that the LT2600's "algorithm" measured impedance via voltage and current. *Id.* Accordingly, a reasonable Jury could have found that the LT2600's "patented grid impedance monitoring algorithm" infringes on the '140 Patent.

Second, Defendants argue that the LT2600 lacks a pulse generator or pulses. Defendants argue that Plaintiffs' own experimental measurements confirmed the difference between the LT2600 and the patented invention. ECF No. 291 at 16. According to Defendants, "[f]or the patented invention, voltage measurements showed 'relatively large spikes and smaller spikes,'

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[2] The parties agreed that the LT2600 and LT2600G chips were identical for purposes of infringement. Day 1 Tr. 177:7–11.

[3] Plaintiffs argue that both of these noninfringement arguments are waived because they were not presented in the Defendants first JMOL. Defendants respond that "CH specifically moved for JMOL of non-infringement citing 'insufficient evidence to establish . . . that Defendants infringe any claim of 'the '140 patent." ECF No. 305 at 9. While the Court is sympathetic to the Plaintiff's arguments here, the Court is not convinced that this amounts to the level of waiver required under Rule 50. *See Navigant*, 508 F.3d at 288.

'somewhat random in their nature.'" *Id.* (citing Day 2 Tr. 239:20–22; Zane DX at 80). For the LT2600 chip, however, measurements did not show "any of those spikes," reflecting a "dramatic difference" in operation. *Id.* (citing Day 2 Tr. 240:7–9; Zane DX at 80). Defendants argue that Plaintiffs do not dispute this evidence and that their "infringement expert testified that the '140 patent's pulses are 'quick changes in voltage,' not in current or impedance, 'that turn on and off a semiconductor switch." Day 1 Tr. 180:25–181:3 (emphasis added); *see id.* at 184:23–24 ("pulse is just a quick voltage on and off").

In response, Plaintiffs contend that their expert "confirmed experimentally that the LT2600 had a pulse generator that generated pulses to control switch CP2." ECF No. 299 at 16 (citing Trial Tr. Day 1 at 180:17–181:3; 180:19–24). Plaintiffs contend that he also "testified that the switch is turned on via the pulse, and also when the light is determined to be properly installed." *Id.* (citing Trial Tr. Day 1 at 188:15–22.) Plaintiffs also contend that the Defendants reliance on the spikes in the data in order to distinguish between the LT2600 and the patented invention comes down to the level of resolution that the was shown. *Id.* Specifically, Plaintiffs contend that Defendants' expert Dr. Zane's "spikes" are just zoomed out views of the pulses that makes it look more random and sporadic. *Id.* However, Plaintiffs argue that their expert showed the Jury these pulses and spikes at different levels of resolution, and the zoomed in view of the graph shows fewer spikes. *See id.* (presenting two graphs of differing levels of resolution).

The Court finds Defendants arguments here to be unconvincing. A reasonable Jury could have found that the LT2600 does not lack a pulse generator or pulses and that the pulses of the patented invention are not different from the LT2600.

In sum, the Court finds that there is substantial evidence to support the Jury's infringement verdict.

iii. Substantial Evidence Supports the Jury's Finding of Willfulness

A determination of willfulness requires a finding of "deliberate or intentional" infringement. *SRI Int'l, Inc. v. Cisco Sys., Inc.*, 14 F.4th 1323, 1330 (Fed. Cir. 2021). "To state a claim for willful infringement, 'a plaintiff must allege facts plausibly showing that as of the time of the claim's filing, the accused infringer: (1) knew of the patent-in-suit; (2) after acquiring that knowledge, it infringed the patent; and (3) in doing so, it knew, or should have known, that its conduct amounted to infringement of the patent.'" *Parity Networks, LLC v. Cisco Sys., Inc.*, No. 6:19-cv-00207-ADA, 2019 WL 3940952, at *3 (W.D. Tex. July 26, 2019) "Willfulness largely turns on intent, which is an issue reserved to the jury." *See WBIP, LLC v. Kohler Co.*, 829 F.3d 1317, 1341 (Fed. Cir. 2016). The Jury found that Defendant CH willfully infringed all of the asserted patents. ECF No. 230 at 5. Defendants ask the Court to grant a JMOL on willfulness. ECF No. 291 at 17–18.

As a preliminary matter, the Defendants recognize that given that the Court "granted enhanced damages, CH recognizes JMOL on willfulness is unlikely." *Id.* (citing ECF No. 286 at 4–20). Defendants thus throw the kitchen sink at trying to attack Jury's verdict finding that CH willfully infringed the asserted patents in order to "preserve their arguments for appeal." *Id.* According to Defendants, "Plaintiffs based their willfulness case on arguments that CH ignored emails alleging infringement, copied Plaintiffs' products, raised no infringement defenses, never redesigned products, and were advised by a subsequently terminated attorney to avoid and delay merits litigation." *Id.* (citing Day 4 Tr. 43:3–22).

First, Defendants argue that Plaintiffs based their willfulness case on arguments that CH ignored emails alleging infringement, but Defendants contend that "[u]nrebutted evidence at trial showed that Ms. Gan rarely paid attention to emails, had never seen the emails from Super

Lighting, and 'would not be able to read them and understand them' because they were in English." *Id.* Plaintiffs respond that "it was certainly reasonable for the jury to reject the myriad inconsistent stories Defendants presented at trial. CH's president, Caiying Gan, variously testified that: (1) she does not check email (despite having an email address prominently displayed on her business card) (Trial Tr. Day 1 at 211:5–11, 214:6–11); (2) she did not receive the emails, (*id.* at 213:13–17, 215:5–25); (3) she received the emails but did not open them, (id. at 214:14–18, 214:19–215:4); (4) she did not read the emails because they were written in English, (*id.* at 213:13–17, 214:14–18); and (5) she does not know how to work her laptop, (*id.* at 216:10–16)." ECF No. 299 at 6. The Court agrees. The Jury was certainly free to find that neither Ms. Gan nor Defendants were credible—this is supported by substantial evidence.

Second, Defendants argue that the alleged copying was rejected by this Court. ECF No. 291 at 18 (citing ECF No. 286 at 7). The Plaintiffs do not respond to this, and the Court agrees with the Defendants. However, the allegations of copying that were introduced at trial are insufficient to support a JMOL of no willfulness.

Third, Defendants contend that CH never admitted infringement, and that the agreement that led CH to drop non-infringement in part was not admissible under the Federal Rules of Evidence. ECF No. 291 at 18. Plaintiffs respond that CH's admission "was clear, unambiguous, and repeated multiple times." ECF No. 299 at 5. Plaintiffs cite "15 times" that this infringement admission was repeated before the Court. *Id.* The Court agrees with the Plaintiffs and finds that this does not support a JMOL of no willfulness.

Fourth, Defendants contend that the Plaintiffs' argument at trial that CH never redesigned products fails for similar reasons. ECF No. 291 at 19. Defendants contend that Defendants believed—and continue to believe—that their invalidity defenses obviate the need for redesign and that their lack of redesign is not evidence of "malicious" or "bad-faith" conduct. *Id.* The Plaintiffs do not respond to this, and the Court agrees with the Defendants. However, the Court finds that the allegations that the defendants failed to redesign that were introduced at trial are insufficient to support a JMOL of no willfulness.

Fifth, Defendants contend that Plaintiffs' arguments about an email from counsel that CH terminated during trial supports a JMOL of no willfulness because it was privileged and lacks probative value. ECF No. 291 at 19. Plaintiffs respond that the Defendants waiver argument "flies in the face of this Court's July 12, 2021 rulings holding that Mr. Jiang and Defendants' counsel waived any privilege over the purported opinions of counsel and ordering documents like PX 326 to be produced." ECF No. 299 at 7 n.5. The Court agrees with Plaintiffs and finds that its rulings finding privilege to be waived do not support a finding of JMOL of no willfulness.

In sum, for similar reasons that this Court found in granting enhancement of damages (ECF No. 281), the Court finds that there is substantial evidence to support the Jury's finding of willful infringement of the asserted patents. The Court does not find the Defendants' arguments to the contrary to be convincing.

In conclusion, the Court having considered all of the arguments in the Defendants' brief and the applicable law, finds that Defendants have not met their burden to grant JMOL on any of their identified grounds. Thus, the Court DENIES their motion for JMOL.

III. MOTION FOR NEW TRIAL

A. Legal Standard

The Court has discretion to grant a new trial "based on its appraisal of the fairness of the trial and the reliability of the jury's verdict." *Smith v. Transworld Drilling Co.*, 773 F.2d 610, 612– 13 (5th Cir. 1985). "A new trial will not be granted based on trial error unless, after considering the record as a whole, the court concludes that manifest injustice will result from letting the verdict stand." *Foradori v. Harris*, 523 F.3d 477, 506 (5th Cir. 2008). "To justify a reversal based on improper comments of counsel, the conduct must be such as to gravely impair the calm and dispassionate consideration of the case by the jury." *Dixon v. Int'l Harvester Co.*, 754 F.2d 573, 585 (5th Cir. 1985). The moving party must timely object and show that the conduct went "far beyond the bounds of accepted advocacy before [the] court must grant a new trial." *Geoffrion v. Nationstar Mortg. LLC*, 182 F. Supp. 3d 648, 673 (E.D. Tex. 2016) (citing *Edwards v. Sears, Roebuck & Co.*, 512 F.2d 276, 284 (5th Cir. 1975)); *see also Baisden v. I'm Ready Prods., Inc.*, 693 F.3d 491, 509 (5th Cir. 2012). The burden is on the moving party to show a new trial is warranted. *Sibley v. Lemaire*, 184 F.3d 481, 487 (5th Cir. 1999).

B. Discussion

Defendants move for a new trial for three primary reasons. ECF No. 292 at 1. First, Defendants request a new trial in light of the allegedly "erroneous grant of JMOL and evidentiary errors regarding invalidity." *Id.* Second, Defendants request a new trial in light of the alleged "failure of Plaintiffs' damages expert to apportion the value of the asserted patents." *Id.* Third, Defendants request a new trial in light of the other alleged "evidentiary error as well as inflammatory statements by Plaintiffs' counsel." *Id.* As explained below, the Court finds that none of these alleged errors warrant granting Defendants a new trial.

i. The Court properly granted JMOL on invalidity of the '125 and '540 Patents and excluded evidence

Defendants move for a new trial based on the Court's grant of partial JMOL for Plaintiffs on invalidity of the '125 and '540 Patents. *Id.* at 2. At trial, CH's expert, Dr. Michael Lebby, testified that claim 1 of the '125 patent and claims 13 and 14 of the '540 patent were invalid in light of three LED tube lamp products, the Cree LED T84821L40K tube (the "Cree tube"), the MaxLite G Series L18T8DF440-G tube (the "MaxLite tube"), and the Philips InstantFit LED T816.5W/48-3500 tube (the "Philips tube"). ECF No. 238 ("Day 2 Tr.") 282:25–300:3. As part of his opinion, Dr. Lebby explained that the Cree, MaxLite, and Philips tubes were prior art because they were on sale in 2014, before the '125 and '540 patents' February 12, 2015 priority date. Day 2 Tr. 291:10–14. The Court, however, ordered partial JMOL for Plaintiffs on invalidity. It reasoned that Dr. Lebby's testimony that the Cree, MaxLite, and Philips tubes were prior art available in 2014 could not constitute sufficient evidence to send the issue to the Jury because the evidence on which he based his opinion was not "in the record" at trial. ECF No. 239 ("Day 3 Tr.") 76:11–18; *see id.* 48:24–53:9, 73:18–82:1.

Defendants contend that "Rule 703 and precedent make clear that expert testimony is itself evidence; the evidence on which an expert relies need not even be admissible, much less actually admitted." ECF No. 292 at 2. Defendants argue that Dr. Lebby's testimony that the Cree, MaxLite, and Philips tubes were "on sale in 2014," Day 2 Tr. 282:12–23 (Cree), 285:22–24 (MaxLite), 289:18– 25 (Philips), was itself sufficient evidence to support a Jury finding that those products were prior art. *Id.* at 3.

Defendants' argument here—that Dr. Lebby's testimony alone, without personal knowledge, the purported prior art products themselves, or any documents about them—can invalidate a patent flouts law Defendants cite in their concomitant JMOL motion. ECF No. 291 at 3 ("'[C]onclusory, unsupported assertions,' even by an expert, cannot defeat JMOL."). Without the physical tubes, specification sheets, or photographs in evidence, Defendants asked Dr. Lebby whether the tubes were on sale in time to qualify as prior art. Although he agreed, his opinion had no foundation. He admitted he had no personal experience with the tubes. ECF No.

281 at 24. He had not spoken to anyone about them, or heard a witness testify about them. (*See, e.g.*, Trial Tr. Day 2 at 276:10–277:8; 317:13–319:6.) And he could not point to a document in evidence that established they were on sale. *See generally id.* at 271:25–309:15.

Defendants' own JMOL motion explains that "conclusory, unsupported assertions," even by an expert, cannot create issues of fact. ECF No. 291 at 3 (citing *Kampen v. Am. Isuzu Motors, Inc.*, 157 F.3d 306, 318 (5th Cir. 1998) (en banc). This is unsurprising, given that Rule 702(b) dictates opinion testimony must be "based on sufficient facts or data." It is well-settled that there must be substantial evidence in the record for a matter to go to the Jury. *Wechsler v. Macke Int'l Trade Inc.*, 486 F.3d 1286, 1294 (Fed. Cir. 2007) (denying JMOL was error where "expert presented little more than conclusory evidence").

Parties may contest expert testimony at trial and seek JMOL where no reasonable jury could find that the other side carried its burden of proof. Here, Dr. Lebby did so little—he did not take the photographs, direct taking the photographs, know who took the photographs, or follow up on the physical items in the photographs—that no reasonable jury could credit his invalidity theory. Defendants are not entitled to a new trial when they failed to "get critical system art into evidence before [they] closed their case." ECF No. 281 at 12.

Defendants further argue that a new trial is required based on the Court's exclusion of a litany of various invalidity evidence. ECF No. 292 at 6–12. *First*, Defendants contend that the prior art light tubes were erroneously excluded. *Id.* They argue these warrant a new trial based on when the Court granted JMOL on CH's invalidity defenses based on the Cree, MaxLite, and Philips tubes, the Court indicated it would not have done so if CH had admitted into evidence the tubes themselves. *Id.* They argue two reasons why the Court allegedly erred in excluding this evidence. The Defendants first argue that the Court erred in excluding the tubes because the tubes had in fact been produced. *Id.* They argue that the tubes were produced during discovery and available for inspection by Plaintiffs no later than June 2020. The Court, however, gave Defendants' counsel multiple opportunities to explain why they should be allowed to go the Jury. Trial Tr. Day 2 at 9:13–17:7. Ultimately, the Court ruled that because Dr. Lebby did not physically examine the tubes himself prior to issuing his report, (*Id.* at 14:20–23), because he did not examine them physically prior to his deposition, (*Id.* at 15:3–5), and because the tubes were not physically present at his deposition, (*Id.* at 14:17–19), Dr. Lebby had made "a choice" that he "was prepared to give his report based on only photos and he felt it wasn't necessary to look at the bulbs themselves." *Id.* at 16:6–11. Defendants abandoned using the tubes and blamed prior counsel for relying exclusively on the photographs. *Id.* at 16:12.

Defendants also argue that the tubes should have been admitted because of the "trade inscriptions" on them. ECF No. 292 at 6–12. Yet Defendants failed to make their "trade inscription" argument when the Court was considering these issues on Day 2; they only raised that contention during their Day 3 offer of proof, well after Dr. Lebby had testified. *Id.* (citing Day 3 Tr. at 45:20–22 for trade inscription argument); *see also generally* Trial Tr. Day 2 at 9:13–17:7.) Thus, the "trade inscription" argument was waived.

Second, Defendants argue that the Court erroneously excluded the MaxLite documents because the Court excluded them for a lack of a sponsoring witness. *Id.* According to Defendants, CH timely identified two MaxLite witnesses: Umesh Baheti or another "MaxLite Representative." *Id.* In an order entered on October 27, 2021, the Court found the following:

> "Defendants conceded on October 27, 2021, that they failed to provide notice to Plaintiffs during discovery that Mr. Umesh Baheti would be authenticating MaxLite documents. The Court therefore ORDERS that Eric Marsh, Mr. Baheti's belatedly identified replacement, is excluded as a witness."

Defendants argue that disclosing a corporate representative is sufficient to the notice requirements, and that even if it were not proper, a late-disclosed witness should not be excluded if the late disclosure is "substantially justified or is harmless." *Id.* (citing Fed. R. Civ. P. 37(c)(1)). Upon consideration of the parties' arguments, the applicable law, the Court finds Defendants' arguments unpersuasive and not sufficient to warrant a new trial.

Third, Defendants complain that the Court erroneously excluded two internal documents relevant to invalidity: (1) DX41 and (2) DX98. First, Defendants argue that DX41 was a presentation from August 2014 showing Super Lighting's in-house teardowns of the Cree and Philips tubes—confirming that those products were publicly available in 2014 and therefore prior art. At trial, the Court acknowledged the presentation "may invalidate the patent," but excluded it as "only dealing with inequitable conduct." Day 1 Tr. 5:15–19, 7:12–16. Defendants now argue that DX41 was relevant to invalidity (apart from inequitable conduct) because it showed that Super possessed the Cree and Philips tubes in August 2014. Second, Defendants argue that DX98 was minutes from a Super Lighting strategy meeting, stating that Super's patent strategy was to "[t]urn[ ] . . . what is typically considered to be unpatentable into patents." ECF No. 292 at 12. Defendants contend that "it was highly relevant: It tended to make it more probable that, in accord with its aggressive patent strategy, Super sought and obtained patents that are in fact 'unpatentable.'" *Id.*

Plaintiffs respond that Defendants attempt to justify DX 41 by glossing over which tubes it addresses. ECF No. 297 at 17. They contend that Dr. Lebby's invalidity opinions involved the Philips T816.5T8/48-3500, the Cree LED T8-48-21L-40K, and the MaxLite Direct Fit Model L18T8DF440-G. *Id.* (citing Trial Tr. Day 2 at 315:24–316:13, 317:13–20.) Yet DX 41 does not mention any of those models. All it shows is that Plaintiffs knew about other tubes from Philips, Cree, and MaxLite. While that might matter for inequitable conduct, it is irrelevant to invalidity. The content of DTX-41 has not changed, and Defendants make no better showing about it than they did before, so the Court holds that DTX-41 does not merit a new trial.

In regard to DX98, Plaintiffs respond that Defendants' "own motion confirms it was an inequitable conduct document." ECF No. 287 at 17. The Court agrees. As the Court recognized, that is an inequitable conduct theory. Trial Tr. Day 1 at 94:3–15. DTX-98 never mentions the patents-in-suit or any of Defendants' purported prior art. *See generally* DTX-98, ECF No. 296-10. Accordingly, it has nothing to do with invalidity, and its proper exclusion cannot justify a new trial.

ii. **The Court properly found that Plaintiffs' damages evidence was admissible and sufficient**

Defendants next move for a new trial based on the Court's admission of the Plaintiffs' damages evidence. ECF No. 292 at 12. Specifically, Defendants argue that "[t]he testimony of Plaintiffs' damages expert, Ms. Kindler, should have been excluded and was legally insufficient to prove damages regardless." *Id.* Defendants contend that in order for the Plaintiffs to properly apportion their damages, they "had to prove the value of affixing the LED strip to the tube lamp's 'inner circumferential surface'; for '540 patent, the value of disposing diffusion film directly on the tube lamp; and for the '140 patent, the value of its pulse-based shock-protection system." *Id.* at 13. Defendants contend they did not do so.

As a preliminary matter, Plaintiffs contend that Defendants have improperly included these arguments regarding excluding Plaintiffs' damages evidence in their Motion for a New trial because Defendants are in essence renewing their damages JMOL in their Motion for New Trial instead of their renewed JMOL. ECF No. 297 at 18. Plaintiffs contend that Defendants did not move for JMOL under Rule 50(a) on all damages issues; rather, their request was limited only to

Ms. Kindler's royalty calculation based on the Lunera agreement. *Id.* (citing Trial Tr. Day 3 at 101:12–102:1.)

Accordingly, the Court finds that the Defendants forfeited all other damages grounds for JMOL. *See, e.g.*, *i4i Ltd. P'ship v. Microsoft Corp.*, 598 F.3d 831, 845 (Fed. Cir. 2010), *aff'd*, 564 U.S. 91 (2011). To the extent Defendants now object to the admissibility of Ms. Kindler's testimony where they failed to object at trial, a new trial motion is an improper vehicle for their objections. *Navigant Consulting, Inc. v. Wilkinson*, No. 3:02-CV-2186-B, 2006 WL 2422868 (N.D. Tex. Aug. 22, 2006) (citing *Johnson v. Michelin Tire Corp.*, 812 F.2d 200, 210 n.8 (5th Cir. 1987)) (denying new trial motion after failure to object to allegedly inadmissible testimony)).

The Court finds Defendants' arguments here unpersuasive. Defendants essentially re-urge to the Court the very same arguments that they made in their JMOL on excluding Plaintiffs damages evidence based on the Lunera agreement. ECF No. 292 at 12–17. They contend that Ms. Kindler proposed a per-unit royalty of $0.30–$0.45. *Id.* (citing Day 2 Tr. 76:24–77:8). According to Defendants, "[s]he derived that figure from past licenses with (1) Technical Consumer Products ("TCP") . . . and (2) Lunera Lighting." *Id.* Defendants argue that both licenses, however, covered "all" of Super's intellectual property, including over 260 patents. *Id.* Defendants thus contend that "[r]ather than apportion down to the patents here, Ms. Kindler applied the royalty rates for over 260 patents to just three patents—indeed, she inflated those rates." *Id.*

Plaintiffs respond that their "expert Ms. Kindler explained to the Jury how, when considering the Lunera license's impact on the hypothetical negotiation, upward influences like the direct competition between Super Lighting and CH Lighting would counterbalance downward factors like the wider breadth of the IP rights being granted to Lunera. ECF No. 297 at 19 (citing Trial Tr. Day 2 at 57:23–61:9). Thus, Plaintiffs contend that, "[w]hile Defendants may disagree with Ms. Kindler's conclusion, her methodology is consistent with *Georgia-Pacific*, and the Jury was free to credit her opinions over those of Defendants' expert." *Id.*

Defendants primarily rely on *Apple Inc. v. Wi-LAN Inc.*, 25 F.4th 960, 973–74 (Fed. Cir. 2022), to support its argument that Ms. Kindler's royalty calculation should have been excluded and thus a new trial is warranted. Because Plaintiffs did not initially address this intervening precedential Federal Circuit opinion in their briefing on Defendants' motion for a new trial, the Court asked the parties for supplemental briefing on this point. *See* ECF Nos. 319–21.

In *Wi-LAN*, the Federal Circuit vacated a damages award and ordered a new trial on damages. *See* 25 F.4th at 972–74. To estimate a reasonable royalty in that case, the patentee's expert culled more than 150 Wi-LAN license agreements down to three comparable agreements. *Id.* The patentee's expert then reduced the rate because unlike the three comparable agreements, a hypothetical negotiation would have resulted in a license to only the asserted patents. *Id.* However, the expert also determined that the two asserted patents were the "key patents" in the three licenses. *Id.* The Federal Circuit disagreed with the district court and ordered a new trial on damages. *Id.* The Federal Circuit found that the expert's opinion that the "the asserted patents were key patents is untethered to the facts of this case." *Id.* According to the Federal Circuit, "[m]ost importantly, those licenses treated the asserted patents as chaff, not wheat." *Id.* The Court found significant that the "there is no evidence that the '757 patent was discussed during negotiations for any of the comparable licenses." *Id.* For both of the asserted patents, the Federal Circuit found that none of the comparable licenses treated them as the key patents. *Id.*

Here, Ms. Kindler's testimony was more than sufficiently reliable and does not require a new trial under *Wi-LAN*. *Wi-LAN* represents one paradigm of patent litigation: an assertion entity (Wi-LAN) suing one of the world's largest operating companies (Apple) for a royalty on every unit of its flagship product (the iPhone). Because Wi-LAN's only business is licensing, the two sides' experts had access to at least 150 potential benchmarks for the hypothetical negotiation. 25 F.4th at 971. Not surprisingly, the experts in that case selected very different licenses as "comparable" agreements for their respective damages models. Thus, Wi-LAN was essentially a dispute about which licenses should be considered in the first instance, not how to apply relevant, agreed-upon licenses.

Apple's expert focused on Wi-LAN's licenses with multinational cellphone companies—LG, Kyocera, Motorola—and giant chipmaker Intel, whose businesses, legal sophistication, and market strength are comparable to Apple's. ECF No. 321-2 at 72, 74. All their licenses were structured as lump sums. *Id.* at 72–74. And an internal Wi-LAN business plan admitted it was "finding it challenging to convince companies to pay license amounts…above single digit millions." *Id.* at 72–73. Apple's expert accordingly estimated damages in a range of $5–$10 million. *Id.* at 68–69.

Wi-LAN's expert took a radically different approach. Eschewing Wi-LAN's licenses with large cellphone makers like Apple, he cherry-picked running royalty licenses Wi-LAN had granted to three niche cellphone providers, Unnecto, Vertu, and Doro.[1] *Id.* at 73–74. Wi-LAN's expert conceded that those licenses were not comparable. ECF No. 321-2 at 322:3–9. Nevertheless, he relied on them and concluded that the two patents-in-suit were "key patents" responsible for the bulk of their value, with thousands of other patents in various technology fields included for a "marginal upcharge." 25 F.4th at 972. To account for that, the expert reduced the royalty by 25%. *Id.* at 973.

But the two "adjustments" were as cherry-picked as the licenses. Wi-LAN defended the patents-in-suit as its "crown jewels," *id.* at 972, yet its CEO admitted that negotiations focused on particular patents not because of their inherent value, but because Wi-LAN chose to introduce them into the licensing discussions. ECF No. 321-4 at 30–31. Wi-LAN's expert was thus forced to concede that any subset of patents could be "key." ECF No. 321-2 at 56, 59–60; ECF No. 321-3 at 29–30. Moreover, one of the two patents-in-suit was omitted in two licenses and listed as "Non-Asserted" in the third, while the second patent was omitted in one license and listed as "Non-Asserted" in another. 25 F.4th at 973. Only one patent's inclusion in the Vertu agreement justified Wi-LAN's rate. *Id.*

Wi-LAN's 25% reduction was equally arbitrary. The Federal Circuit assumed the number came from Wi-LAN's CEO, *id*. at 973, but the briefs and testimony below show that the CEO testified such adjustments for additional patents "might" happen "sometimes." ECF No. 321-2 at 62; ECF No. 321-5 at 158:1–10.) No one identified a single license where such a markup occurred. ECF No. 321-2 at 62. Most important, there was no evidence that the Unnecto, Vertu, and Doro licenses had been adjusted in this way. *Id.* at 61–62. Wi-LAN was left with no support for the 25% reduction except its expert's "experience" generally. *Id.* at 59. And, because he admitted he would have applied the reduction to any subset of patents, ECF No. 321-2 at 59–60, ECF No. 321-4 at 30–31, his 25% figure was arbitrary.

This case is completely different. The litigants here are not a massive non-practicing entity and the world's largest electronics manufacturer, but "archrivals" in the LED lightbulb business. As operating companies in a narrow market, they have engaged in limited patent licensing; there was no ready pile of 150 licenses to "cull through" here. Instead, the licenses available were real-world licenses from the relevant industry. Accordingly, unlike in *Wi-LAN*, the experts here agreed that the licenses Kindler addressed were technologically comparable. *See, e.g.*, Day 2 Tr. at 62:1–9; Day 3 Tr. at 28:13–16. They also agreed on the format of the license, i.e., a per-unit running royalty (Day 2 Tr. at 45:13–46:13, 335:1–18), and on the royalty base (Day 3 Tr. at 25:11–20, 28:10–12).

CH's expert Mooney formulated his running royalty from the same agreements as Kindler. *Compare* Day 3 Tr. at 18:17–25:15, *with* Day 2 Tr. at 53:1–62:7. The Court finds that this resolves any question whether Kindler's reliance on the licenses merits a new trial. *See, e.g.*, *Pavo Sols. LLC v. Kingston Tech. Co.*, 35 F.4th 1367, 1378–80 (Fed. Cir. 2022) (denying JMOL where parties agreed a license was comparable); *Bio-Rad Lab'ys., Inc. v. 10X Genomics Inc.*, 967 F.3d 1353, 1374 (Fed. Cir. 2020) (affirming denial of new trial where district court concluded licenses had "baseline comparability" and remaining "degree of comparability" was for the jury). CH "cannot legitimately challenge the comparability of its own comparable." *Versata Software, Inc. v. SAP Am., Inc.*, 717 F.3d 1255, 1268 (Fed. Cir. 2013).

The parties' experts did disagree on how to apply the licenses they both deemed comparable, and Mooney calculated a per-unit rate while Kindler calculated a dollar amount. Day 2 Tr. at 69:11–23, 335:1–18. But such differences are to be expected because comparable licenses are almost never identical to the hypothetical negotiation. *See, e.g.*, *Ericsson Inc. v. D-Link Sys., Inc.*, 773 F.3d 1201 (Fed. Cir. 2014) ("[T]he fact that a license is not perfectly analogous generally goes to the weight of the evidence, not its admissibility."); *Virnetx, Inc. v. Cisco Sys., Inc.*, 767 F.3d 1308, 1330 (Fed Cir. 2014). "[A]ny reasonable royalty analysis 'necessarily involves an element of approximation and uncertainty.'" *Lucent Techs., Inc. v.*

Gateway, Inc., 580 F.3d 1301, 1325 (Fed. Cir. 2009) (quoting *Unisplay, S.A. v. Am. Elec. Sign Co.*, 69 F.3d 512, 517 (Fed. Cir. 1995)). CH's suggestion that Kindler did "nothing" to adjust the agreed-upon licenses is as wrong now after trial as it was at the Daubert stage. CH wrongly assumes that because Kindler's ultimate estimate was close to the terms of the actual agreements, she must have made no adjustments. But as to the TCP license, Kindler laid out her adjustments over five pages of trial testimony. Day 2 Tr. at 53:1–57:21, 58:20–61:12. All this testimony was presented without objection. Moreover, Ms. Kindler did not apply an arbitrary reduction factor, like Wi-LAN's expert did, but rather accounted for the actual economic relationships between Super Lighting, TCP, and CH.

Ultimately, the Court finds that *Wi-LAN* does not require overturning the Jury's verdict here because of the many fundamental differences between the two cases. The Court also bears in mind that CH is arguing for a new trial, which should be granted only when "prejudicial error has crept into the record or … substantial justice has not been done." *Jordan v. Maxfield & Oberton Holdings, L.L.C.*, 977 F.3d 412, 417 (5th Cir. 2020). Here, Kindler's comparable-license analysis was just one factor in her complete 15-factor Georgia-Pacific analysis. She specifically testified about factors 5, 8, 11, and 13 in addition to factor 1. *See, e.g.*, Day 2 Tr. at 49:13–50:11. *Wi-LAN* has no bearing on the other Georgia-Pacific factors, including factor 5's focus on competition between the parties. The Court finds that it made no prejudicial error, and substantial justice was done. Thus, Defendants' motion for a new trial on damages is DENIED.

iii. **The alleged inflammatory statements do not warrant a new trial**

Defendants next move for a new trial based on this Court's alleged evidentiary errors and alleged inflammatory argument. The Court rejects each of these arguments in turn.

First, Defendants argue that the Court should have not admitted an email between CH and its prior counsel because it was privileged. ECF No. 292 at 17. Defendants contend that it was erroneous for the Court to find that Jack Jiang "opened the door" to admission of privileged communications by testifying that it took CH many months to find counsel. *Id.* (citing Day 2 Tr. 147:7–151:15). Defendants further contend that Plaintiff's Counsel relied on the admission of this email to make "inflammatory representations about CH's litigation conduct" that was "deeply prejudicial and require a new trial." *Id.* at 19. Specifically, Defendants contend that they were prejudiced by counsel's repeated assertion that CH was "looking to avoid and delay the lawsuit because they didn't want to respond on the merits," "because they have no legitimate defenses." *Id.* at 18 (citing Day 4 Tr. 35:9–14). Defendants further contend that the Plaintiffs improperly "inflamed" the Jury by reiterating Defendants' concession of infringement. ECF No. 292 at 18–19.

In response, Plaintiffs first argue that nothing about its trial presentation was inflammatory. ECF No. 297 at 3. Plaintiffs demonstrate how the jury instructions told the jury that Defendants had stipulated to infringement. *See id.* According to the Plaintiffs, "[i]f there was no 'admission,' as Defendants now claim, why did they not object to these jury instructions?" *Id.* at 4. Plaintiffs also contend that the Defendants failed to object all the other times the infringement admission was raised, and therefore, "Defendants agreed to this as a factual matter." *Id.* As for the so-called delay and avoid email, Plaintiffs assert that "any privilege attached to the DELAY and AVOID email was vitiated months earlier through Mr. Jiang's and counsel's own behavior." *Id.* at 5. Specifically, Plaintiffs explained that after Mr. Jiang brought up the communications during a deposition, Plaintiffs sought to compel and asked for a finding of waiver—and the Court agreed. *Id.* at 6. The Court ruled that the communications from counsel "now ha[ve] become information that could be used to impeach Mr. Jiang." *Id.* at 6. At trial, Plaintiffs argue that "[g]iven [a] pattern of inconsistent testimony and the direct falsehoods Mr. Jiang provided the jury, Plaintiffs had no choice but to impeach him with PTX-326. That document shows that Mr. Jiang did know of the lawsuit in January 2020, he had retained counsel at that point, and Defendants were pursuing a strategy of delaying or avoiding the lawsuit." *Id.* at 7. Plaintiffs conclude by arguing that "PTX-326 hardly had the outsized impact that Defendants suggest." *Id.* at 8. According to Plaintiffs, "Defendants cannot show that this single document tipped the balance of the verdict." *Id.*

In reply, Defendants first contend that "CH did not 'waive' privilege by producing the document pursuant to a court order." ECF No. 306 at 9. Defendants further contend that privilege was not waived by Mr. Jiang's deposition testimony about opinions of counsel on "infringement and invalidity." *Id.* Defendants argue that the Court rejected the Plaintiffs' claim that the "email contradicts Mr. Jiang's testimony," declaring it not to be "evidence that CH had a strategy of avoiding litigating this Action in Texas." *Id.* (quoting ECF No. 286 at 28–29). Defendants argue that "even if the email were relevant to show when CH retained counsel, that was not grounds to admit the email's substance." *Id.* Defendants argue that the Plaintiffs used the email to inflame the Jury throughout the trial and raised the email with CH's invalidity and damages expert. *Id.* at 9–10.

The Court finds that the Defendants' alleged evidentiary errors regarding the delay and avoid email and corresponding alleged inflammatory argument are unpersuasive and do not warrant a new trial. The Court finds that it properly admitted the delay and avoid email. Any privilege regarding the email was waived. Moreover, the Plaintiffs' use of the email at trial did not inflame the Jury. The Court finds that this one document, regardless of its admissibility, was not enough to sway the verdict in this case. Accordingly, the Court rejects granting a new trial based on this email alone.

The Court further finds that Plaintiffs' arguments regarding Defendants' concession of infringement are not prejudicial and do not require a new trial. It is clear from the record that Defendants conceded infringement and the Defendants failed to object to such a concession. Clear and express, that admission was a stipulated fact that Plaintiffs had every right to cite, and the Jury had every right to rely upon. Nothing about Plaintiffs' behavior was improper or inflaming.

Second, Defendants argue that the Court's exclusion of Super Lighting's analysis (DX41) warrants a new trial because it "was admissible on willfulness as well as invalidity" and "[i]ts exclusion unfairly prejudiced CH by giving the jury a one-sided view." ECF No. 292 at 19. According to Defendants, Plaintiffs had introduced CH's internal analysis of Plaintiffs' products as supposed evidence of willful copying. *Id* (citing Day 4 Tr. 32:15–19). To rebut that claim, CH sought to introduce Plaintiffs' analysis of other competitors' products to show it was "common practice" in the industry "to review competitor products." *Id.*

The Court finds, as it did above, that DX41 was properly excluded. Any purported relevance that DX41 has on willfulness is insufficient to warrant a new trial.

Third, Defendants assert that the Court's exclusion of the Lumixess documents warrants a new trial. *Id.* According to Defendants, "[t]hose documents show that CH was not willful because it relied on Lumixess to analyze whether the LT2600 chip practiced the Super Lighting's shock-protection system, and thus lacked the "specific intent to infringe" required for willfulness." *Id.* Defendants contend that the Court erred by excluding the documents as hearsay because "CH did not offer the Lumixess documents for their truth (i.e., to show the LT2600 chip did not infringe), but for the non-hearsay purpose of showing the state of mind they induced—i.e., CH's knowledge of and reliance on Lumixess's analysis." *Id.*

In response, Plaintiffs argue that the Court properly excluded these documents because of Defendants' own procedural errors. ECF No. 297 at 15–16. According to Plaintiffs, Defendants ignored this Court's rule that documentary exhibits require a sponsoring witness. Rather than taking a timely deposition testimony or obtaining a custodial affidavit, Defendants did nothing to meet the sponsoring witness requirement until pressed by the Court at the motion in limine hearing. In reply, Defendants again reiterate that a new trial is warranted because the Court allegedly erred by excluding the Lumixess documents because it was admissible for a non-hearsay purpose. ECF No. 306 at 10.

The Court agrees with Plaintiffs and find that the Court's exclusion of the Lumixess documents does not warrant a new trial. The documents could not be admitted without a sponsoring witness, irrespective of hearsay. Fed. R. Civ. P. 901. When pressed at the motion in limine hearing, Defendants attempted to explain why the Lumixess documents were not hearsay without addressing Rule 901. ECF No. 190 at 5:20–8:5. Mr. Jiang, through whom Defendants hoped to introduce the documents, had no personal knowledge and was thus unqualified to authenticate them. *Id.* at 6:4–7:2. Defendants' motion merely repeats their failed hearsay arguments and continues to ignore authentication. Defendants have once again failed to address the shortcoming of the Lumixess documents, and no new trial is warranted on the basis of their exclusion.

IV. MOTION FOR SUPPLEMENTAL DAMAGES, ONGOING ROYALTY, AND ENHANCEMENT OF POST-VERDICT DAMAGES

A. Legal Standard

i. Supplemental Damages

Under 35 U.S.C. §284, upon a finding of infringement, a prevailing "patentee is entitled to damages for the entire period of infringement and should therefore be awarded supplemental damages for any periods of infringement not covered by the jury verdict." *ActiveVideo Networks, Inc. v. Verizon Commc'ns, Inc.*, No. 2:10CV248, 2011 WL 4899922, at *2, *4 (E.D. Va. Oct. 14, 2011) (citing *TiVo, Inc. v. Echostar Commc'ns Corp.*, 2006 U.S. Dist. LEXIS at *6 (E.D. Tex. Aug. 17, 2006)). "[S]upplemental damages are compensatory in nature" and "calculated in accordance with the damages awarded in the jury verdict." *Id.* at *2 (citations omitted). The Court has "discretion to award damages for periods of infringement not considered by the jury." *Whitserve, LLC v. Computer Packages, Inc.*, 694 F.3d 10, 38 (Fed. Cir. 2012).

ii. Ongoing Royalty

It is within the Court's equitable discretion to determine whether an ongoing royalty need be imposed. *See Paice LLC v. Toyota Motor Corp.*, 504 F.3d 1293, 1314–15 (Fed. Cir. 2007). Although an ongoing royalty is not automatic, "the Federal Circuit has indicated that a prevailing patentee should receive compensation for any continuing infringement." *Apple, Inc. v. Samsung Elecs. Co.*, No. 12-CV-00630-LHK, 2014 WL 6687122, at *7 (N.D. Cal. Nov. 25, 2014) (citing *Telcordia Techs., Inc. v. Cisco Sys., Inc.*, 612 F.3d 1365, 1379 (Fed. Cir. 2010)).

In determining the ongoing royalty rate, the Court must consider: (i) the "change in the parties' bargaining positions, and the resulting change in economic circumstances, resulting from the determination of liability,"; (ii) "changed economic circumstances, such as changes related to the market for the patented products,"; and (iii) any other "post-verdict factor" that would impact "what a hypothetical negotiation would look like after the prior infringement verdict." *XY, LLC v. Trans Ova Genetics, L.C.*, 890 F.3d 1282, 1297 (Fed. Cir. 2018). "Generally, the jury's damages award is a starting point for evaluating ongoing royalties." *Apple, Inc.*, 2014 WL 6687122, at *14 (citing *Bard Peripheral Vascular, Inc. v. W.L. Gore & Assocs., Inc.*, 670 F.3d 1171, 1193 (Fed. Cir. 2012), *vacated on other grounds*, 467 F. App'x 747. In addition, the Court may consider the Georgia-Pacific factors. *Arctic Cat Inc. v. Bombardier Recreational Prods. Inc.*, 876 F.3d 1350, 1370 (Fed. Cir. 2017).

iii. Enhanced Damages

Section 284 of Title 35 provides that, in a patent infringement case, "the court may increase the damages up to three times the amount found or assessed." 35 U.S.C. § 284. As the Supreme Court has remarked in the seminal *Halo* decision, "That language contains no explicit limit or condition, and we have emphasized that the word 'may' clearly connotes discretion." *Halo Elecs., Inc. v. Pulse Elecs., Inc.*, 579 U.S. 93, 103 (2016) (cleaned up). That discretion is not boundless and instead must be exercised "in light of considerations underlying the grant of that discretion." *Id.* (cleaned up). In interpreting those considerations, the Supreme Court appealed to the judiciary's 180-year history of awarding enhanced damages, in which courts have "generally reserved" enhancement for "egregious cases of culpable behavior." *Id.* at 104. Egregious cases typically involve, in the Court's opinion, conduct that is "willful, wanton, malicious, bad-faith, deliberate, consciously wrongful, flagrant, or—indeed—characteristic of a pirate." *Id.* at 103–04; *id.* at 107 ("[S]uch punishment should generally be reserved for egregious cases typified by willful misconduct.").

"Willfulness largely turns on intent, which is an issue reserved to the jury." *See WBIP, LLC v. Kohler Co.*, 829 F.3d 1317, 1341 (Fed. Cir. 2016). Once the jury finds that the defendant's infringement was willful, the Court must consider whether that alone justifies enhancement. According to the Federal Circuit, "Halo emphasized that subjective willfulness alone . . . can support an award of enhanced damages." *WesternGeco L.L.C. v. ION Geophysical Corp.*, 837 F.3d 1358, 1362 (Fed. Cir. 2016), *rev'd on other grounds*, 138 S. Ct. 2129, 201 L. Ed. 2d 584 (2018); *Halo*, 579 U.S. at 105 ("The subjective willfulness of a patent infringer, intentional or knowing, may warrant enhanced damages, without regard to whether his infringement was objectively reckless."). Yet courts are vested with discretion to forbear enhancement under § 284 even in egregious cases, if that is what "the particular circumstances of" the case demand. *Id.* at 106; cf. *id.* at 111 (Breyer, J., dissenting) ("[W]hile the Court explains that 'intentional or knowing' infringement 'may' warrant a punitive sanction, the word it uses is may, not must . . . . It is 'circumstanc[e]' that transforms simple knowledge into such egregious behavior, and that makes all the difference."). The Federal Circuit has endorsed consideration of the *Read* factors to "assist the trial court in evaluating the degree of the infringer's culpability and in determining whether to exercise its discretion to award enhanced damages at all, and if so, by how much the damages should be increased." *WCM Indus., Inc. v. IPS Corp.*, 721 F. App'x 959, 972 (Fed. Cir. 2018). As to burdens, the "party seeking enhanced damages under § 284 bears the burden of proof by a preponderance of the evidence." *WBIP*, 829 F.3d at 1339.

B. Discussion

Now that judgment has been entered, Super Lighting asks the Court to impose each of the following remedies:

- $0.45 per unit for each of the Undisclosed Pretrial Sales, a total of $531,559.80.

- $0.45 per unit for each of the sales representing the Supplemental Damages, a total of $3,872,688.30.
- Prejudgment interest of $18,774.39 on these amounts.
- An ongoing royalty of $0.45 per unit for all infringing products and products not colorably different sold after the entry of judgment
- An additional $0.45 per unit of enhancement on each of the Supplemental Damages sales and Ongoing Sales.

ECF No. 287 at 2. Since its original Motion was filed, Plaintiff filed a notice with the Court updating the above amounts as listed below.

- Additional supplemental damages of $442,771 from CH Lighting since the last sales update, totaling $4,274,812 (on 9,499,583 total infringing sales) since the Jury verdict.
- Additional supplemental damages of $5,781 from Elliott since the last sales update, totaling $44,949 (on 87,039 total infringing sales) since the Jury verdict.
- Additional enhanced damages of $441,292 from CH Lighting since the last sales update, totaling $4,274,812 since the Jury verdict.
- Post-judgment interest of $777 per day for CH Lighting and $4.51 per day for Elliott.

ECF No. 317 at 1–2.

The Court will address each of these requested remedies below.

i. Undisclosed Pretrial Sales

Super Lighting argues that Defendants should not be spared from paying damages for its 1.2 million units of undisclosed pretrial sales. ECF No. 287 at 10. According to Super Lighting, the only reason those sales were not presented to the Jury is because Defendants did not produce them. *Id.* To be clear, Super Lighting is not saying this withholding of unit numbers was nefarious; the parties agreed to a pretrial financial update as presenting real-time information during trial would have been impractical and burdensome. *Id.* But Super Lighting argues that is exactly why the parties expressly agreed in the Joint Pretrial Order that "the amount adequate to compensate Plaintiffs for… past and ongoing infringement" was still at issue. *Id.* (citing ECF No. 173 at 11). Nor did Defendants object to the verdict form, which explicitly asked the Jury to decide only the amount of damages that Super Lighting had proven for Defendants' "past infringement." *See id.* (citing ECF No. 230 at 4). Super Lighting contends that Defendants cannot now backtrack on its agreements to obtain a windfall, particularly one that would result only because Defendants' data was withheld from Super Lighting and the Jury. *Id.*

In response, Defendants argue that despite receiving CH's sales data months before judgment entered—and mere days after they asked—Plaintiffs never moved for supplemental damages or an ongoing royalty. ECF No. 300 at 9. According to Defendants, although Plaintiffs filed extensive motions seeking entry of a judgment awarding many kinds of relief (ECF Nos. 233, 234, 241, 242), they never asked to be awarded those pretrial sales they now demand before judgment. *Id.* Thus, Defendants argue that Plaintiffs ignore Rule 59(e)'s limits because this evidence of "Undisclosed Pretrial Sales" is not newly discovered. *Id.*

In reply, Super Lighting asserts that its motion was timely. ECF No. 303 at 4. Even if its motion were solely based on Rule 59(e), Super Lighting argues that Rule says such motions must be brought within 28 days of a judgment: the exact same timing as a new trial motion under Rule 59(b). *Id.* Judgment here was entered on July 29; 28 days after July 29 was August 26. As such, Super Lighting contends that its August 19 motion was inside the 28-day window. *Id.* According to Super Lighting, despite all of Defendants' arguments about the time that passed between the verdict and entry of judgment, ECF No. 300 at 11, "during that period Plaintiffs made absolutely no secret that they were pursuing supplemental and ongoing damages." *Id.* Thus, Super Lighting contends that there was no waiver.

Courts have routinely awarded damages in circumstances such as these, and there is no good reason to proceed otherwise here. *See, e.g., Genband US LLC v. Metaswitch Networks Corp.*, No. 2:14-CV-00033-JRG, 2018 WL 11357619, at *10–14 (E.D. Tex. Mar. 22, 2018); *PCT Int'l Inc. v. Holland Elecs. LLC*, 2016 WL 1241875, at *18–19 (D. Ariz. 2016); *ActiveVideo Networks, Inc. v. Verizon Commc'ns, Inc.*, No. 2:10CV248, 2011 WL 4899922, at *4–5 (E.D. Va. Oct. 14, 2011); *Hynix Semiconductor Inc. v. Rambus Inc.*, 609 F. Supp. 2d 951, 960–61 (N.D. Cal. 2009); *Mondis Tech. Ltd. v. Chimei InnoLux Corp.*, 822 F. Supp. 2d 639, 642 (E.D. Tex. 2011) ("[w]hen the jury awarded damages in this case, it did not have before it the sales data for the first and second quarter of 2011… [plaintiff] is entitled to supplemental damages for those two quarters"), *aff'd sub nom.*, *Mondis Tech. Ltd. v. Innolux Corp.*, 530 F. App'x 959 (Fed. Cir. 2013).

The Court agrees with Super Lighting that it should be awarded for the 1.2 million units of undisclosed pretrial sales. Because the Court has "discretion to award damages for periods of infringement not considered by the jury," *Whitserve*, 694 F.3d at 38, the 1.2 million units sold between CH Lighting's final pretrial production of sales data and the November 4, 2021 verdict yields $523,871 in damages at the Jury-approved $0.45 royalty rate. Likewise, the 17,086 units sold between Elliott's final pretrial production of sales data and the November 4, 2021 verdict yields $7,688.70in damages at the Jury-approved $0.45 royalty rate. Accordingly, the Court finds that such an amount should be added to the existing Judgment under the Court's inherent accounting authority and Rule 59(e). Similarly, the Court is also persuaded that Super Lighting's motion was timely and there was no waiver by Super Lighting.

ii. Supplemental Damages

Super Lighting next moves to include supplemental damages on the 8.6 million units Defendants sold after the Jury's willful infringement verdict but before the Court entered judgment.[4] ECF No. 287 at 12–13. Like the above finding that Super Lighting should be awarded supplemental damages on the Undisclosed Pretrial Sales, the Court finds that Super Lighting is also entitled to damages on the units Defendants sold after the Jury's willful infringement verdict but before the Court entered judgment. As it did above, the Court rejects the Defendants' arguments here against awarding these supplemental damages to Super Lighting for similar reasoning.

The Court finds that supplemental damages are necessary and appropriate here to fully compensate Super Lighting for Defendants' infringement. Accordingly, the Court finds that Defendants must pay the $4,319,761 in supplemental damages ($4,274,812 from CH Lighting and $44,949 from Elliott) by adding that amount to the existing judgment under the Court's inherent accounting authority. Similarly, the Court is also persuaded that Super Lighting's motion was timely and there was no waiver by Super Lighting.

iii. Pre-Judgment Interest

[4] On December 2, 2022, Super Lighting provided an update on the sales amount requested for their motion for supplemental damages. ECF No. 317. In it, Super Lighting notes that Defendants have since provided updated sales data for the third quarter of 2022, indicating that CH Lighting sold 994,328 additional units of infringing products, earning $3,346,998 in revenue, while Elliott sold 16,132 units of infringing products. *Id.* at 1. Based on Defendants' latest sales figures, there have been additional supplemental damages of $442,771 from CH Lighting since the last sales update, totaling $4,274,812 (on 9,499,583 total infringing sales) since the Jury verdict, and additional supplemental damages of $5,781 from Elliott since the last sales update, totaling $44,949 (on 87,039 total infringing sales) since the Jury verdict.

A prevailing plaintiff in a patent infringement action is entitled to compensation that is "in no event less than a reasonable royalty for the use made of the invention by the infringer, together with interest and costs as fixed by the court." 35 U.S.C. § 284. Therefore "complete compensation" for the defendant's infringement includes prejudgment interest awarded from the date of infringement to the date of judgment. *Gen. Motors Corp. v. Devex Corp.*, 461 U.S. 648, 655 (1983); *Nickson Indus., Inc. v. Rol Mfg. Co.*, 847 F.2d 795, 800 (Fed. Cir. 1988). As this Court has recognized, "[t]he purpose of prejudgment interest is to place the patentee in as good a position as he would have been had the infringer paid a reasonable royalty rather than infringe." *VLSI Tech. LLC v. Intel Corp.*, No. 6:21-CV-57-ADA, 2022 WL 1477728, at *1 (W.D. Tex. May 10, 2022) (quoting *SSL Servs., LLC v. Citrix Sys., Inc.*, 769 F.3d 1073, 1094 (Fed. Cir. 2014) (internal quotation marks omitted)). "Accordingly, prejudgment interest on a damages award "is the rule, not the exception." *Id.* (quoting *Energy Transp. Grp., Inc. v. William Demant Holding A/S*, 697 F.3d 1342, 1358 (Fed. Cir. 2012) (internal quotation marks omitted)).

Super Lighting contends that it should also be awarded prejudgment interest on the Undisclosed Pretrial Sales and Supplemental Damages awarded by the Court. ECF No. 287 at 19. The Court agrees. The Court's Order previously resolved several disputes between the parties concerning the application of prejudgment and post-judgment interest to the damages award, including the applicable interest rates and what portions of the damages award accrue interest. ECF No. 286 at 39–40. As those issues have been resolved, the Court will apply the same treatment of these issues to the amended judgment and to the supplemental damages awarded above.

iv. Post-Judgment Interest

Pursuant to 28 U.S.C. §1961, post-judgment "[i]interest shall be allowed on any money judgment in a civil case recovered in a district court." 28 U.S.C. §1961(a). The interest is calculated at the Federal statutory rate of the weekly average 1-year constant maturity Treasury yield, computed daily and compounded annually. *Id*. § 1961(a)–(b); *VLSI*, 2022 WL 1477728, at *4 (holding prevailing patentee "is entitled to an award of post-judgment interest at the federal statutory rate"). Post-judgment interest on a money judgment begins to accrue "from the date of the Court's final judgment until the date of payment." *VLSI*, 2022 WL 1477728, at *4.

Super Lighting contends that it should also be awarded post-judgment interest on the Undisclosed Pretrial Sales and Supplemental Damages awarded by the Court. ECF No. 287 at 19. The Court agrees. The Court's Order previously resolved several disputes between the parties concerning the application of prejudgment and post-judgment interest to the damages award, including the applicable interest rates and what portions of the damages award accrue interest. ECF No. 286 at 39–40. As those issues have been resolved, the Court will apply the same treatment of these issues to the amended judgment and to the supplemental damages awarded above.

v. Ongoing Royalty

Super Lighting moves for the Court to award ongoing royalties for the Defendants' continuing infringement post-judgment. ECF No. 287 at 14. Defendants respond that Super Lighting has not justified an ongoing royalty because such royalties must be "'based on a post-judgment hypothetical negotiation using the *Georgia-Pacific* factors'" and "it allegedly failed to "consider 'additional evidence of changes in the parties' bargaining positions and other economic circumstances that may be of value.'" ECF No. 300 at 14–15 (citing *ActiveVideo Networks, Inc. v. Verizon Commc'ns, Inc.*, 694 F.3d 1312, 1343 (Fed. Cir. 2012). According to

Defendants, Ms. Kindler's declaration offers no opinion on a hypothetical post-judgment negotiation, and she mechanically applies "a royalty rate of $0.45, consistent with the jury's verdict." *Id.*

Super Lighting replies that Defendants' arguments are unfounded because no authority requires that Plaintiffs get nothing because they did not present a new Georgia-Pacific analysis on the ongoing royalty. ECF No. 303 at 7. Super Lighting also contends that to the extent any "change[] in the parties' bargaining positions and other economic circumstances" is relevant here, those factors favor Plaintiffs and an increased rate now that willful infringement, validity, and infringement have been conclusively determined. *Id.* at 8 (citing *XY, LLC v. Trans Ova Genetics*, 890 F.3d 1282, 1298 (Fed. Cir. 2018) (reversing district court for lowering the jury-awarded royalty rate without justification); *Amado v. Microsoft Corp.*, 517 F.3d 1353, 1361–62 (Fed. Cir. 2008)).

The Court finds that, consistent with the Jury's verdict in this case, Super Lighting is entitled to an award of an ongoing royalty for post-judgment infringement in the amount of $0.45 per unit. Defendants' only evidence that the rate determined by the Jury and by Ms. Kindler should be adjusted downward is Ms. Kindler's evidence about falling LED prices. ECF No. 300 at 15–17. Yet Ms. Kindler testified that decline was due to Defendants' infringement. ECF No. 238, Trial Tr. Day 2 at 55:18–56:13. Nevertheless, any "change[] in the parties' bargaining positions and other economic circumstances" is relevant here, those factors favor Super Lighting and an increased rate now that willful infringement, validity, and infringement have been conclusively determined. *See XY, LLC v. Trans Ova Genetics*, 890 F.3d 1282, 1298 (Fed. Cir. 2018). Although Defendants also complain that Super Lighting's motion for ongoing royalty was untimely and waived, the Court finds—like it did above—that Super Lighting's motion was not untimely and not waived. Thus, the Court awards Super Lighting an ongoing royalty for post-judgment infringement in the amount of $0.45 per unit.

vi. Enhanced Damages

Super Lighting finally moves to be awarded enhanced damages for CH Lighting's continued willful infringement after the Jury verdict. ECF No. 287 at 16. According to Super Lighting, the Court's ability to enhance damages under 35 U.S.C. § 284 applies with equal force "[i]n either event" whether the damages are found by the jury or assessed by the Court, and therefore the Court may enhance post-verdict supplemental damages and ongoing royalties. *See SynQor*, 709 F.3d at 1385

CH Lighting responds that "[e]ven if the Court were to award supplemental damages, it should not enhance those damages." ECF No. 300 at 19. CH Lighting contends that because the "Court previously declined to enhance parts of the damages award, based on its determination that 'Defendants developed a good-faith belief that they were not infringing by the time they filed an answer to Plaintiffs' complaint,'" the supplemental damages should not be enhanced because CH Lighting continues to believe in good faith that the Asserted Patents are invalid.

Here, the Jury has already found that CH Lighting's infringement was willful, and the Court has already found that this case is egregious and that enhancement is warranted. For example, the Court previously recognized CH Lighting's disregard of the risk from Super Lighting's patent portfolio (ECF No. 286 at 8–10), the Jury's "quick and lopsided decision" (*id.* at 15), the duration of CH Lighting's misconduct (*id.* at 16), the lack of remedial actions (*id.* at 16–17), CH Lighting's motivation to harm Super Lighting including its decision to "poach" Jack Jiang with "unusually large benefits" as well as its "reckless disregard" for the harm to Super Lighting (*id.* at 17–18), and its misrepresentation of the Court's orders and withholding of information relevant to willfulness during litigation (*id.* at 18–19). These reasons for enhancement continue to apply to CH Lighting's post-verdict infringement with at least the same force.

None of the *Read* factors have changed in a way that weighs against enhancement, and several factors now weigh even more heavily in favor of enhancement. 970 F.2d 816, 826–27 (Fed. Cir. 1992); ECF No. 286 at 6. Regarding *Read* factors 2 (good-faith belief regarding defenses) and 5 (closeness of the case), the Court finds that CH Lighting can no longer maintain a good-faith belief that it either does not infringe or that the patents are invalid, after CH Lighting either withdrew such defenses or the Jury quickly rejected them. *Read* factor 6 (duration of misconduct), now weighs more heavily in favor of enhancement since CH Lighting has continued to infringe for another nine months and counting after the Jury found it to willfully infringe. Continuing to infringe even after the Court admonished CH Lighting for its "egregious" conduct in its Order weighs even more heavily in favor of enhancement. *Read* factor 7 (remedial actions) weighs more heavily in favor of enhancement now that CH Lighting has shown that it has no intention to take any remedial action whatsoever for its continued infringement and the harm caused to Super Lighting. As to *Read* factor 8 (Defendant's motivation), the Court has previously noted the tight competition between Super Lighting and CH Lighting in a small market and that CH Lighting's continued infringement shows at least "reckless disregard for the harm it has and continues to cause to a rival." ECF No. 286 at 18. CH Lighting's continued sales of infringing products illustrate that its motivation to take and maintain its market share at Super Lighting's expense outweighed any concern about Super Lighting's patent rights, the Jury's verdict, and this Court's orders. While CH Lighting's ongoing decision to keep infringing post-verdict and even after the Court's enhancement order could support an increase in enhancement, the Court finds that applying the Court's previously decided doubling of damages to post-verdict sales (including ongoing royalties) is entirely fair and reasonable. Indeed, because the evidence at trial shows that CH Lighting makes a profit of $1.08 per unit on the infringing tubes (ECF No. 238 at 70:17–71:2), doubling the Jury's $0.45 award to $0.90 per unit would still allow CH Lighting to turn a profit, even for sales made in the face of admitted infringement, a Jury verdict, and enhancement by this Court. Accordingly, the Court grants Super Lighting's Motion to enhance damages on CH Lighting's post-verdict sales by the same factor of two that the Court found in its previous Order (ECF No. 286). The Court, however, declines Super Lighting's invitation to enhance ongoing royalties.

V. CONCLUSION

It is therefore **ORDERED** that

- Defendants' Motion for Judgment as a Matter of Law, ECF No. 291, is **DENIED**;
- Defendants' Motion for New Trial, ECF No. 292, is **DENIED**;
- Plaintiffs' Motion for Supplemental Damages, Ongoing Royalty and Enhancement of Post-Verdict Damage, ECF No. 287, is **GRANTED-IN-PART**.
- The Court's previous **ORDER** (ECF No. 322) is hereby **VACATED** and **SUPERSEDED**

It is **FURTHER ORDERED** that entry of final judgment is **HELD IN ABEYANCE** pending the parties' resolution of the precise dollar amount of enhancement and supplemental damages the Court has ordered. The parties are hereby instructed to do the following: meet and confer regarding the dollar amount of enhancement and supplemental damages the Court ordered above; and jointly draft a proposed order of final judgment consistent with the rulings above, to be sent to the Court by March 15, 2023, on which date the Court will enter final judgment.

SIGNED this 8th day of March, 2023.

ALAN D ALBRIGHT
UNITED STATES DISTRICT JUDGE

IN THE UNITED STATES DISTRICT COURT
FOR THE WESTERN DISTRICT OF TEXAS
WACO DIVISION

JIAXING SUPER LIGHTING ELECTRIC APPLIANCE CO., LTD. AND OBERT, INC.,

Plaintiffs,

v.

CH LIGHTING TECHNOLOGY CO., LTD., ELLIOTT ELECTRIC SUPPLY INC., AND SHAOXING RUISING LIGHTING CO., LTD.,

Defendants.

CASE NO. 6:20-CV-00018-ADA

ORDER OF FINAL JUDGMENT

This action came before the Court for trial by jury commencing on November 1, 2021, between Plaintiffs Jiaxing Super Lighting Electric Appliance Co., Ltd. and Obert, Inc. (collectively "Super Lighting" or "Plaintiffs") and Defendants CH Lighting Technology Co., Ltd. and Shaoxing Ruising Lighting Co. Ltd. (collectively "CH Lighting"), and Elliott Electric Supply Inc. ("Elliott") (collectively "Defendants"). The issues have been tried and the jury rendered its unanimous verdict on November 4, 2021 (ECF No. 230). In accordance with the jury verdict and the Court's rulings at trial and on the parties' post-trial motions (ECF Nos. 221, 286, 323), it is hereby **ORDERED** and **ADJUDGED** that:

1. Defendants have each infringed claims 1, 4, 5, 24, 28 and 31 of U.S. Patent No. 9,939,140 (the "'140 patent"), claims 13 and 14 of U.S. Patent No. 10,352,540 (the "'540 patent"), and claim 1 of U.S. Patent No. 10,295,125 (the "'125 patent");
2. CH Lighting's infringement was willful;

3. Claims 1, 4, 5, 24, 28 and 31 of the ’140 patent, claims 13 and 14 of the ’540 patent, and claim 1 of the ’125 patent are not proved invalid;

4. Judgment is hereby entered in favor of Jiaxing Super Lighting Electric Appliance Co., Ltd. and Obert, Inc. and against Defendants in the sum of $31,221,873.81 against CH Lighting and $359,016.71 against Elliott in damages for Defendants’ infringement of the asserted claims, an amount that is the sum of:

    a. $13,872,872 in damages against CH Lighting as awarded by the jury;

    b. $7,155,432 in enhanced damages on the jury’s verdict against CH Lighting, reflecting an award of $0.45 per unit for all infringing products sold between the date CH learned of the ’140 patent, February 16, 2019, and the date when CH Lighting filed its answer, December 3, 2020;

    c. $523,871.10 in damages against CH Lighting for pretrial sales, reflecting an award of $0.45 per unit for all infringing products sold between the parties’ pretrial financial update and the jury verdict;

    d. $4,692,834.90 in supplemental damages against CH Lighting, reflecting an award of $0.45 per unit for all infringing products sold after the jury’s verdict but before the Court entered judgment;

    e. $186,404 in pre-judgment interest at the one-year Treasury Bill constant maturity rate, compounded annually, on the jury verdict against CH Lighting;

    f. $97,624.91 in pre-judgment interest at the one-year Treasury Bill constant maturity rate, compounded annually, on CH Lighting’s pretrial sales and supplemental damages.

g. $4,692,834.90 in enhanced damages on CH Lighting's supplemental damages, reflecting an award of $0.45 per unit for all infringing products sold after the jury's verdict but before the Court entered judgment;

h. $298,454 in damages against Elliott as awarded by the jury;

i. $7,688.70 in damages against Elliott for pretrial sales, reflecting an award of $0.45 per unit for all infringing products sold between the parties' pretrial financial update and the jury verdict;

j. $47,954.25 in supplemental damages against Elliott, reflecting an award of $0.45 per unit for all infringing products sold after the jury's verdict but before the Court entered judgment; and

k. $3,911 in pre-judgment interest at the one-year Treasury Bill constant maturity rate, compounded annually, on the jury verdict against Elliott;

l. $1,008.76 in pre-judgment interest at the one-year Treasury Bill constant maturity rate, compounded annually, on Elliott's undisclosed pretrial sales and supplemental damages.

5. The foregoing sums have been calculated based on sales of the infringing products through January 31, 2023 by CH Lighting. For all infringing products shipped between February 1, 2023 and March 17, 2023, it is hereby **ORDERED** that CH Lighting pay Super Lighting $0.45 in supplemental damages per unit sold. It is further **ORDERED** that for all infringing products shipped between February 1, 2023 and March 17, 2023, CH Lighting pay Super Lighting an additional $0.45 in enhanced damages per unit sold.

6. The foregoing sums have been calculated based on sales of the infringing products through February 28, 2023 by Elliott. For all infringing products shipped between March 1, 2023

and March 17, 2023, it is hereby **ORDERED** that Elliott pay Super Lighting $0.45 in supplemental damages per unit sold.

7. Super Lighting is additionally awarded post-judgment interest, pursuant to 28 U.S.C. § 1961, at the statutory rate of the weekly average 1-year constant maturity Treasury yield, computed daily and compounded annually, from the date of entry of this Judgment until the date of payment. Through March 15, 2023, Super Lighting is awarded post-judgment interest in an amount of $4,311.18 from CH Lighting and $49.57 from Elliott. Post-judgment interest will continue to accrue until the date of payment.
8. Pursuant to Federal Rule of Civil Procedure 54(d), Local Rule CV-54, and 28 U.S.C. § 1920, Super Lighting is the prevailing party in this case and shall recover allowed costs from Defendants, and it is **ORDERED** that Defendants CH Lighting and Elliott will jointly pay Super Lighting $147,420.61 as agreed by the Parties and laid out in their Agreed Bill of Costs (ECF No. 278-1).
9. Super Lighting is awarded an ongoing royalty for post-judgment infringement in the amount of $0.45 per unit, and it is **ORDERED** that CH Lighting and Elliott shall provide an ongoing accounting of sales of infringing products on a quarterly basis, within 45 days of the end of each quarter.
10. The Court hereby **ORDERS** CH Lighting and Elliott to pay Super Lighting the amounts detailed above.
11. The Court **DENIES** all relief not granted in this judgment.
12. This **FINAL JUDGMENT** starts the time for filing any notice of appeal.

SIGNED this 17th day of March, 2023.

ALAN D ALBRIGHT
UNITED STATES DISTRICT JUDGE

FILED
November 04, 2021
CLERK, U.S. DISTRICT COURT
WESTERN DISTRICT OF TEXAS
BY: Jennifer Clark
DEPUTY

IN THE UNITED STATES DISTRICT COURT
FOR THE WESTERN DISTRICT OF TEXAS
WACO DIVISION

JIAXING SUPER LIGHTING ELECTRIC APPLIANCE CO., LTD. AND OBERT, INC.,	§	
Plaintiffs,	§	**CASE NO. 6:20-cv-00018-ADA**
vs.	§	**JURY TRIAL DEMANDED**
CH LIGHTING TECHNOLOGY CO., LTD., ELLIOTT ELECTRIC SUPPLY INC. AND SHAOXING RUISING LIGHTING CO., LTD.,	§	
Defendants.	§	

VERDICT FORM

In answering the following questions, you are to follow all of the instructions I have given you in the Court's Charge. Your answers to each question must be unanimous.

As used herein:

"Super Lighting" refers to *Jiaxing Super Lighting Electric Appliance Co., Ltd. and Obert, Inc.*

"CH Lighting" refers to *CH Lighting Technology Co., Ltd.*

"Ruising" refers to *Shaoxing Ruising Lighting Co., Ltd.*

"Elliott" refers to *Elliott Electric Supply Inc.*

"Defendants" refers collectively to CH Lighting, Ruising, and Elliott.

"The '140 Patent" refers to U.S. Patent No. 9,939,140.

"The '540 Patent" refers to U.S. Patent No. 10,352,540.

"The '125 Patent" refers to U.S. Patent No. 10,295,125.

"The Asserted Patents" refers collectively to the '140 Patent, the '540 Patent, and the '125 Patent.

I. INFRINGEMENT

Directions -- Question 1: In answering the Question below, please check **"Yes"** or **"No"** for each patent claim in the space provided.

Question No. 1: Has Super Lighting proven by a preponderance of the evidence that all of Defendants' accused products containing the LT2600 integrated circuit infringe the following claims of the '140 patent?

"Yes" is a finding for ***Super Lighting****. "No" is a finding for* ***CH Lighting.***

'140 Patent, Claim 1:	Yes ✓	No ____
'140 Patent, Claim 4:	Yes ✓	No ____
'140 Patent, Claim 5:	Yes ✓	No ____
'140 Patent, Claim 24:	Yes ✓	No ____
'140 Patent, Claim 28:	Yes ✓	No ____
'140 Patent, Claim 31:	Yes ✓	No ____

II. VALIDITY

Directions -- Question 2: In answering the Question below, please check **"Yes"** or **"No"** for each patent claim in the space provided.

Question No. 2: Have Defendants proven by clear and convincing evidence that the Asserted Claims of the Asserted Patents are invalidated by the prior art?

"Yes" is a finding for ***CH Lighting****. "No" is a finding for* ***Super Lighting.***

	Yes	No
'540 Patent, Claim 13		✓
'540 Patent, Claim 14		✓
'140 Patent, Claim 1		✓
'140 Patent, Claim 4		✓
'140 Patent, Claim 5		✓
'140 Patent, Claim 24		✓
'140 Patent, Claim 28		✓
'140 Patent, Claim 31		✓

III. DAMAGES

Directions – Answer questions 3 and 4: In answering Questions 3 and 4, please provide a **dollar amount** in the blank spaces.

You must include some amount of damages for at least the '125 Patent, which has been proven valid and infringed. Do not include damages for the '540 Patent if you determine it is invalid. Do not include damages for the '140 Patent if you determine it is invalid. Do not include damages for the LT2600 chip if you determine it does not infringe the '140 Patent.

Question 3: What is the total amount of past damages you find Super Lighting has proven by a preponderance of the evidence for CH Lighting and Ruising's past infringement?

$ 13,872,872.00

Question 4: What is the total amount of past damages you find Super Lighting has proven by a preponderance of the evidence for Elliott's past infringement?

$ 298,454.00

IV. WILLFUL INFRINGEMENT

Directions -- Questions 5A and 5B: In answering the Questions below, please check **"Yes"** or **"No"** in the space provided.

Question No. 5A: Has Super Lighting proven by a preponderance of the evidence that CH Lighting and Ruising's infringement was willful?

"Yes" is a finding for ***Super Lighting****. "No" is a finding for* ***CH Lighting.***

'125 Patent	Yes ✓	No ____
'540 Patent	Yes ✓	No ____
'140 Patent	Yes ✓	No ____

Question No. 5B: Has Super Lighting proven by a preponderance of the evidence that Elliott's infringement was willful?

"Yes" is a finding for ***Super Lighting****. "No" is a finding for* ***Elliott.***

'125 Patent	Yes ____	No ✓
'540 Patent	Yes ____	No ✓
'140 Patent	Yes ____	No ✓

You have now reached the end of the verdict form and should review it to ensure it accurately reflects your **unanimous** determinations. After you are satisfied that your unanimous answers are correctly reflected above, your Jury Foreperson should then sign and date this Verdict Form in the spaces below. Once that is done, notify the Court Security Officer that you have reached a verdict. The Jury Foreperson should retain possession of the verdict form and bring it when the jury is brought back into the courtroom.

I certify that the jury unanimously concurs in every element of the above verdict.

SIGNED this 4 day of November, 2021.

[redacted]

JURY FOREPERSON

US009939140B2

(12) **United States Patent**
Liu et al.

(10) **Patent No.: US 9,939,140 B2**
(45) **Date of Patent: *Apr. 10, 2018**

(54) **LED TUBE LAMP**

(71) Applicant: **JIAXING SUPER LIGHTING ELECTRIC APPLIANCE CO., LTD**, Jiaxing (CN)

(72) Inventors: **Xintong Liu**, Jiaxing (CN); **Aiming Xiong**, Jiaxing (CN); **Tao Jiang**, Jiaxing (CN); **Feng Zou**, Jiaxing (CN)

(73) Assignee: **Jiaxing Super Lighting Electric Appliance Co., Ltd.**, Jiaxing, Zhejiang (CN)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **15/339,221**

(22) Filed: **Oct. 31, 2016**

(65) **Prior Publication Data**

US 2017/0067627 A1 Mar. 9, 2017

Related U.S. Application Data

(63) Continuation-in-part of application No. 15/210,989, filed on Jul. 15, 2016, now Pat. No. 9,587,817, which

(Continued)

(30) **Foreign Application Priority Data**

Sep. 28, 2014 (CN) 2014 1 0507660
Sep. 28, 2014 (CN) 2014 1 0508899

(Continued)

(51) **Int. Cl.**

H05B 37/00 (2006.01)
H05B 41/00 (2006.01)

(Continued)

(52) **U.S. Cl.**

CPC ***F21V 25/02*** (2013.01); ***F21K 9/272*** (2016.08); ***F21K 9/278*** (2016.08); ***F21V 23/005*** (2013.01);

(Continued)

(58) **Field of Classification Search**

None

See application file for complete search history.

(56) **References Cited**

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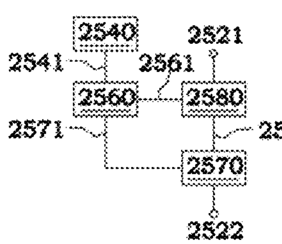
(Continued)

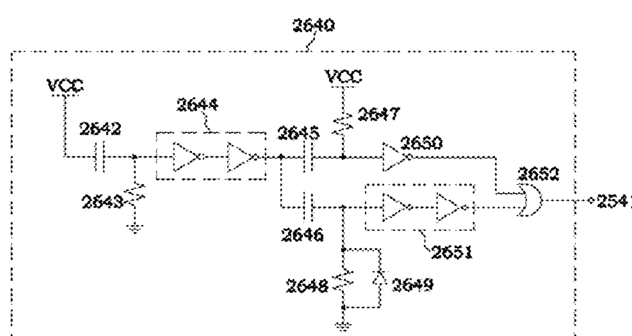
Primary Examiner — Anh Tran
(74) *Attorney, Agent, or Firm* — Muir Patent Law, PLLC

(57) **ABSTRACT**

An LED tube lamp is disclosed. An installation detection circuit is configured in the LED tube lamp configured to receive an external driving signal. The installation detection circuit includes: a pulse generating circuit configured to output one or more pulse signals; wherein the installation detection circuit is configured to detect during one or more pulse signals whether the LED tube lamp is properly installed on a lamp socket, based on detecting a signal generated from the external driving signal; and a switch circuit coupled to the pulse generating circuit, wherein the one or more pulse signals control turning on and off of the switch circuit. The installation detection circuit is further configured to: when it is detected during one or more pulse signals that the LED tube lamp is not properly installed on the lamp socket, control the switch circuit to remain in an off state to cause a power loop of the LED tube lamp to be open; and when it is detected during one or more pulse signals that the LED tube lamp is properly installed on the lamp socket,

(Continued)





control the switch circuit to remain in a conducting state to cause the power loop of the LED tube lamp to maintain a conducting state.

35 Claims, 16 Drawing Sheets

Related U.S. Application Data

is a continuation-in-part of application No. 15/066,645, filed on Mar. 10, 2016, now Pat. No. 9,497,821, which is a continuation-in-part of application No. 14/865,387, filed on Sep. 25, 2015, now Pat. No. 9,609,711, said application No. 15/210,989 is a continuation-in-part of application No. 15/205,011, filed on Jul. 8, 2016, now Pat. No. 9,629,211, which is a continuation-in-part of application No. 15/150,458, filed on May 10, 2016, now Pat. No. 9,794,990, which is a continuation-in-part of application No. 14/865,387, filed on Sep. 25, 2015, now Pat. No. 9,609,711, and a continuation-in-part of application No. 14/699,138, filed on Apr. 29, 2015, now Pat. No. 9,480,109.

(30) **Foreign Application Priority Data**

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(51) **Int. Cl.**

F21V 25/02	(2006.01)
H05B 33/08	(2006.01)
F21K 9/278	(2016.01)
F21V 23/00	(2015.01)
F21K 9/272	(2016.01)
F21V 3/04	(2018.01)
F21Y 115/10	(2016.01)
F21Y 103/10	(2016.01)
F21V 23/02	(2006.01)
F21V 29/83	(2015.01)

(52) **U.S. Cl.**

CPC ***H05B 33/0803*** (2013.01); ***H05B 33/0815*** (2013.01); ***H05B 33/0857*** (2013.01); ***H05B 33/0884*** (2013.01); ***H05B 33/0887*** (2013.01); *F21V 3/0418* (2013.01); *F21V 23/02* (2013.01); *F21V 29/83* (2015.01); *F21Y 2103/10* (2016.08); *F21Y 2115/10* (2016.08); *Y02B 20/346* (2013.01)

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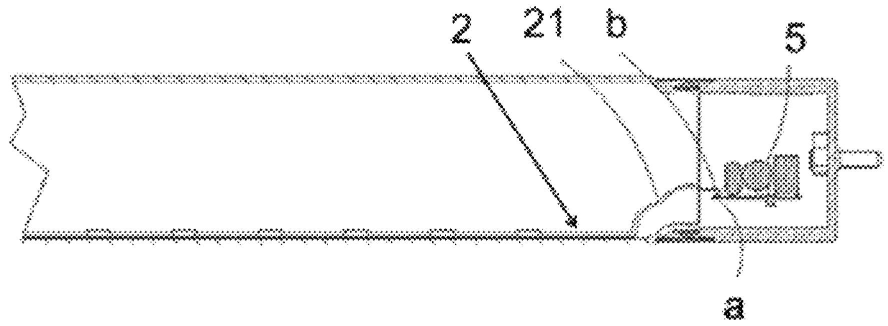

Fig. 1

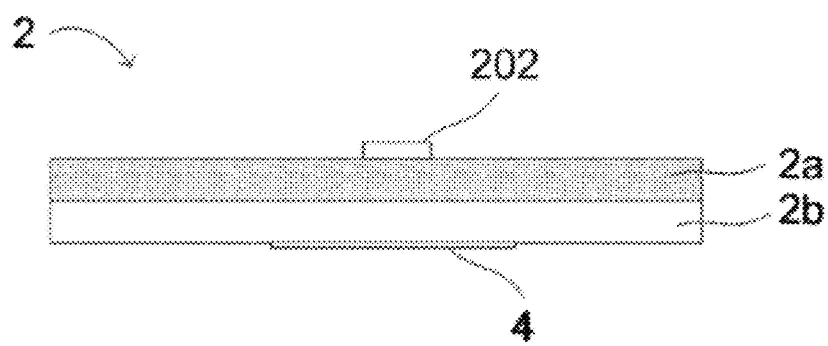

Fig. 2

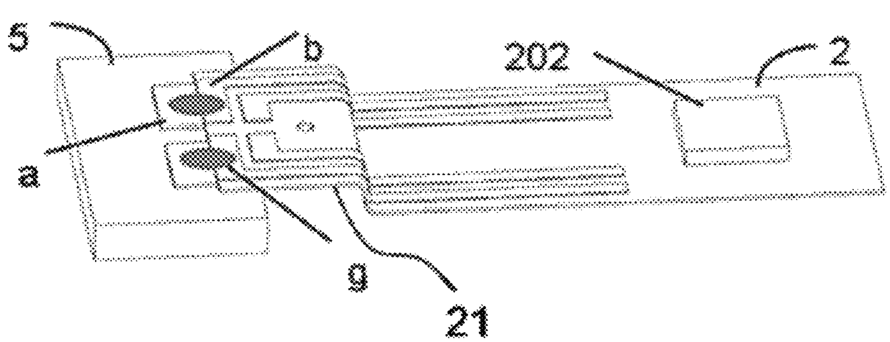

Fig. 3A

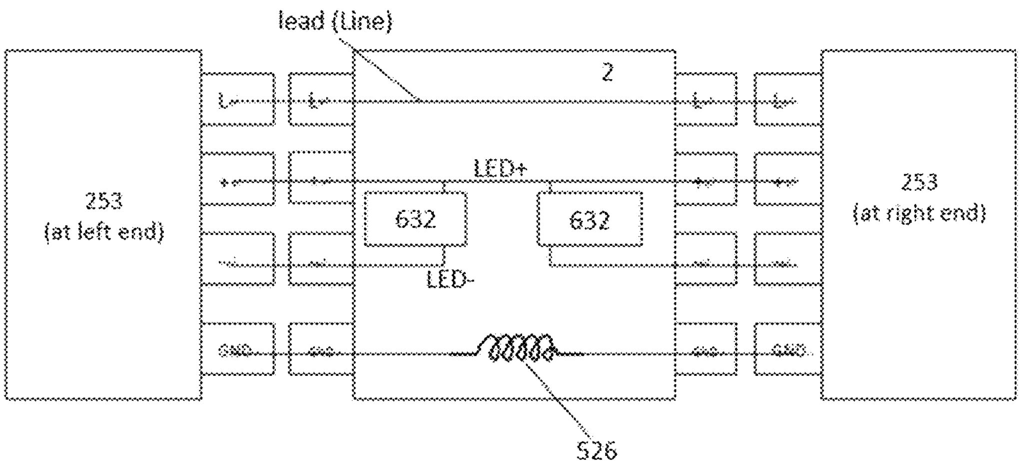

Fig. 3B

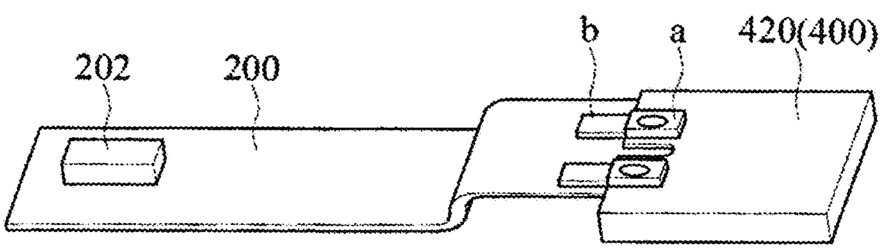

Fig. 4A

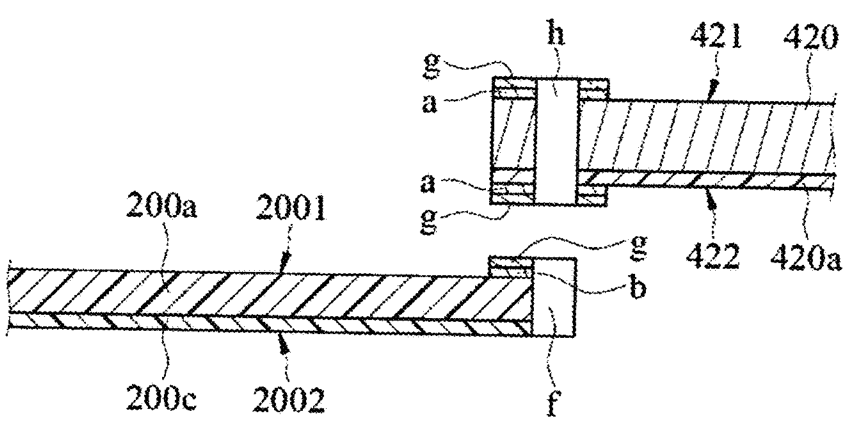

Fig. 4B

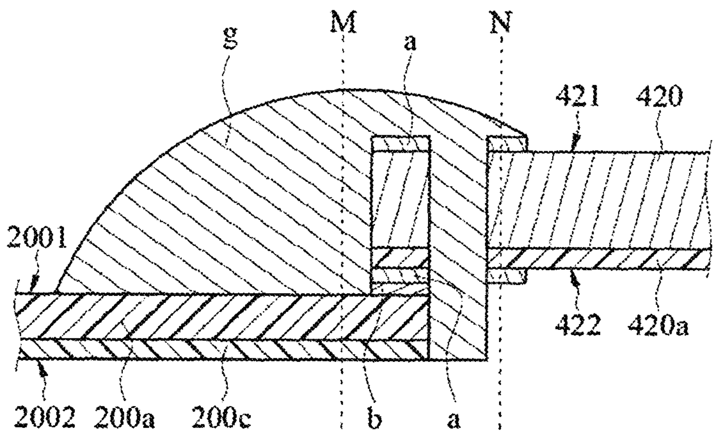

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Fig. 4C

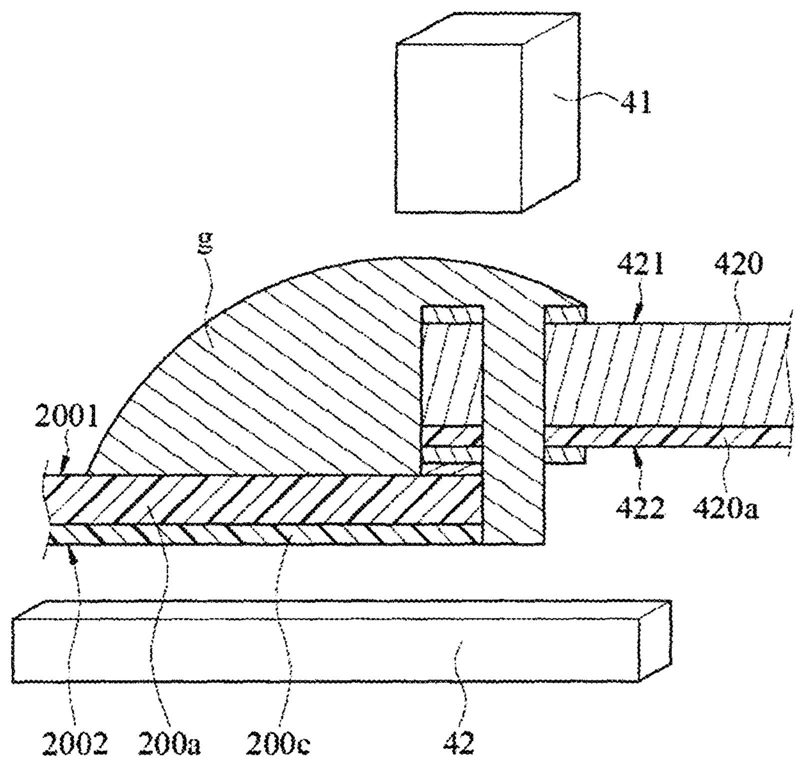

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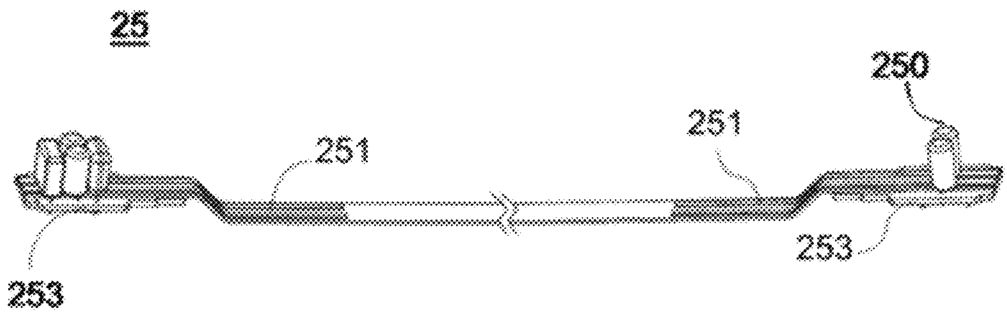
Fig. 4D



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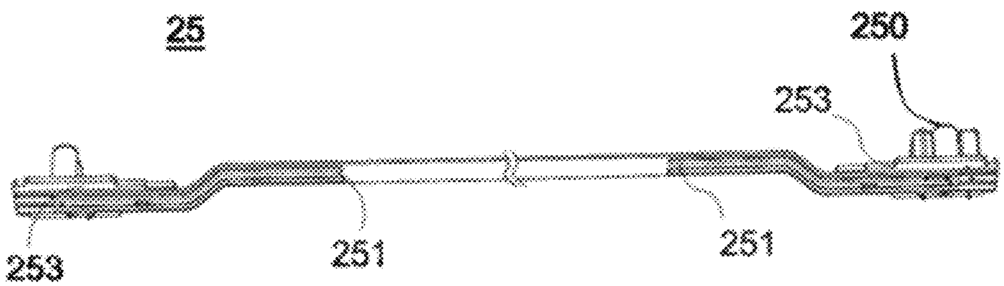


Fig. 6

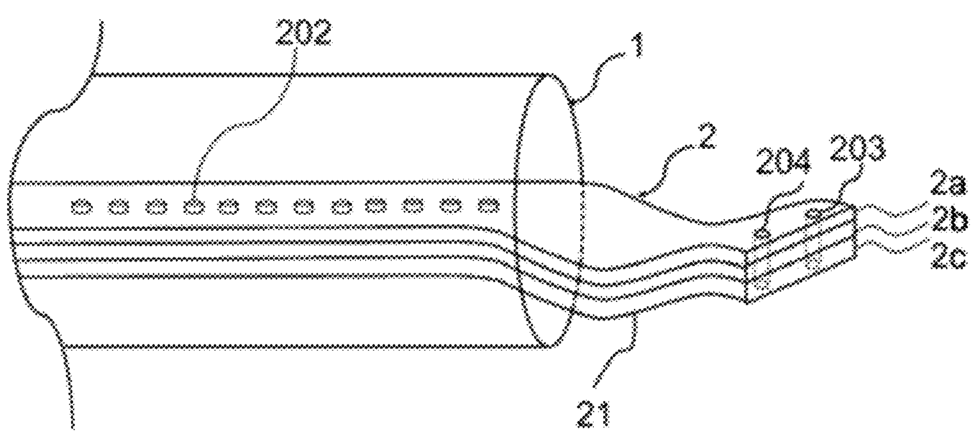


Fig. 7

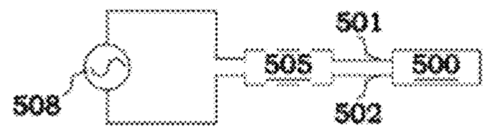


Fig. 8A

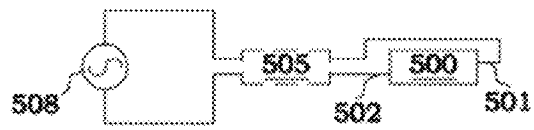


Fig. 8B

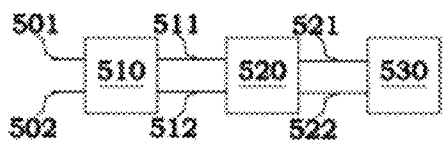


Fig. 8C

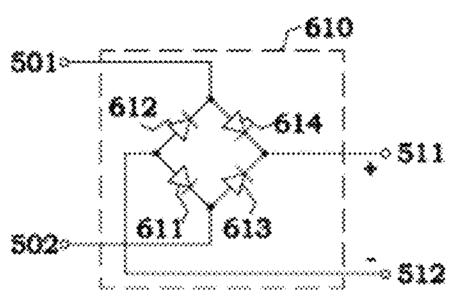


Fig. 9

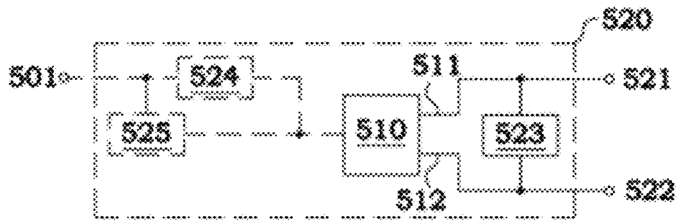
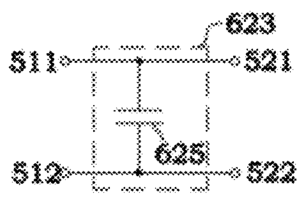


Fig. 10A



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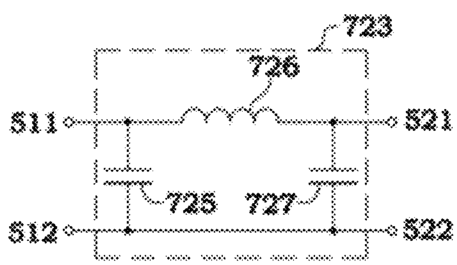


Fig. 10C

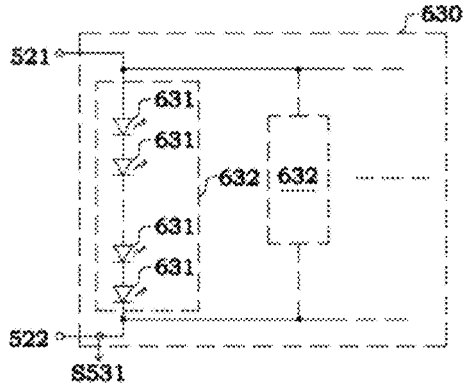
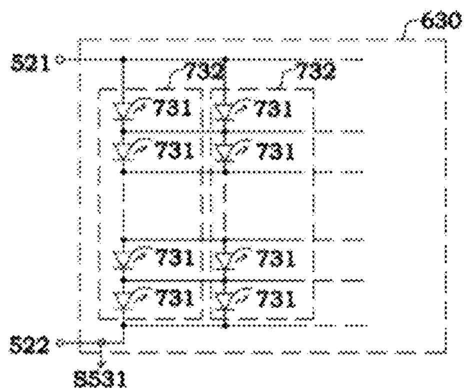


Fig. 11A



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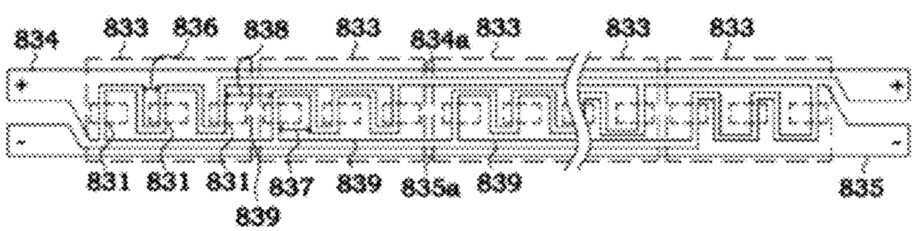

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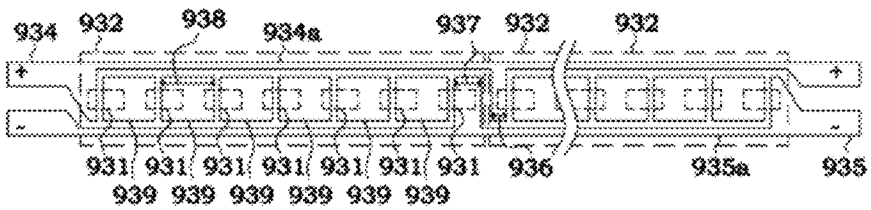


Fig. 11D

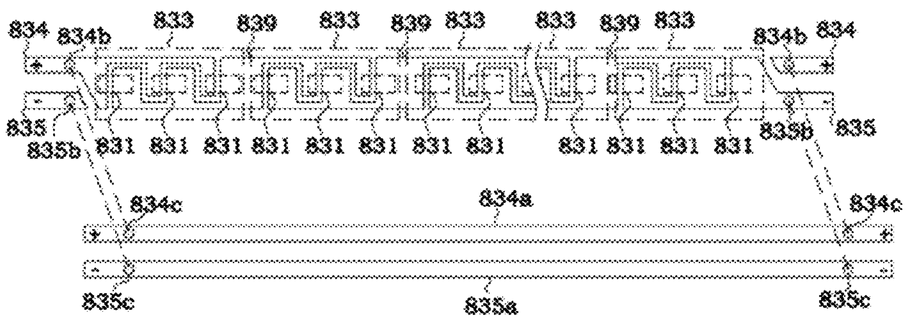


Fig. 11E

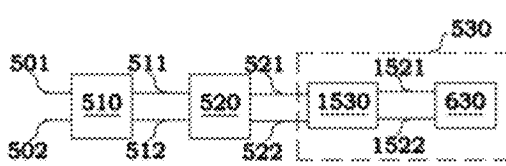


Fig. 12A

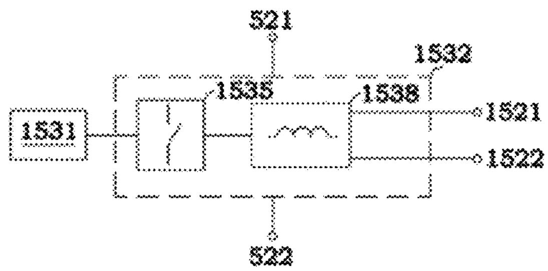


Fig. 12B

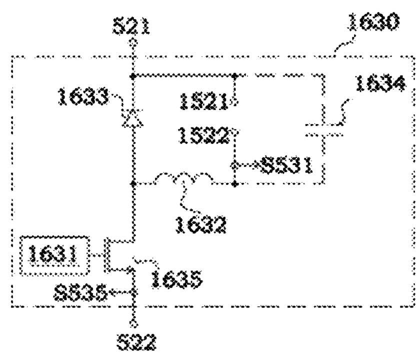
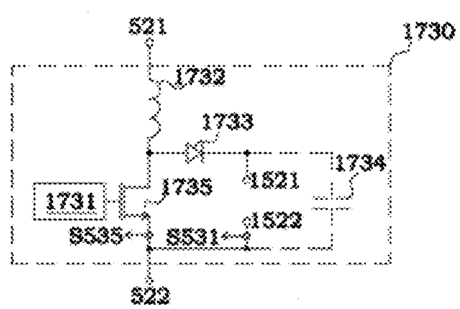


Fig. 12C



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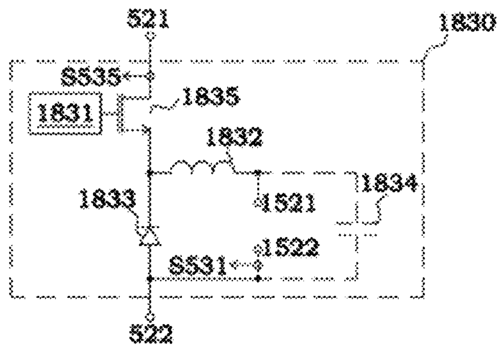

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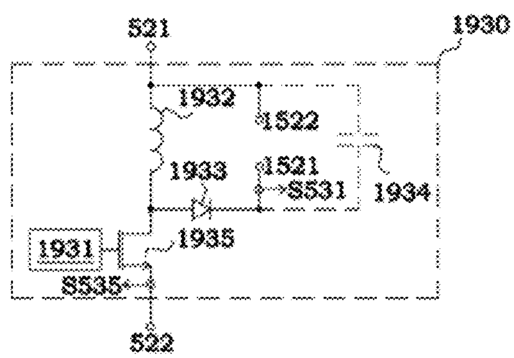

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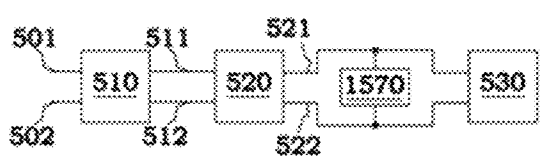

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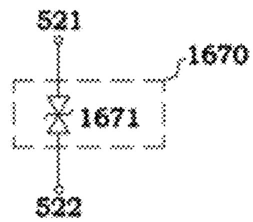

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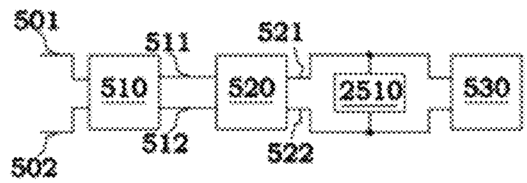


Fig. 14A

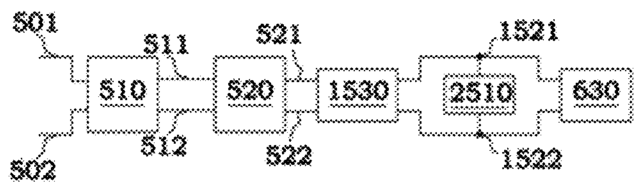


Fig. 14B

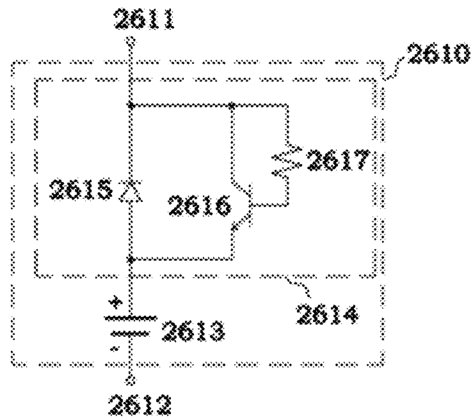


Fig. 14C

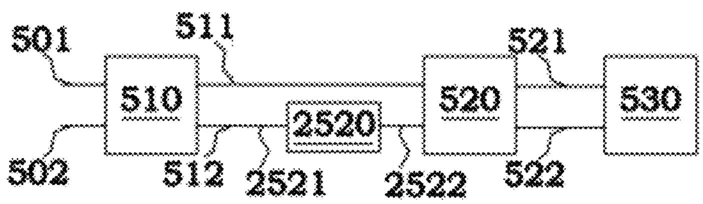
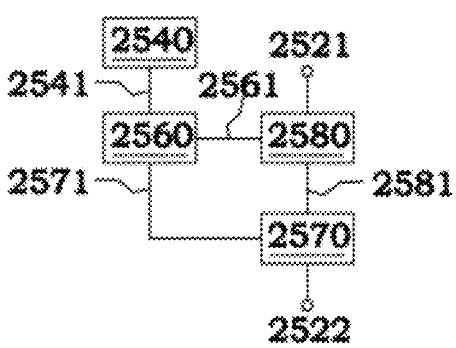


Fig. 15A



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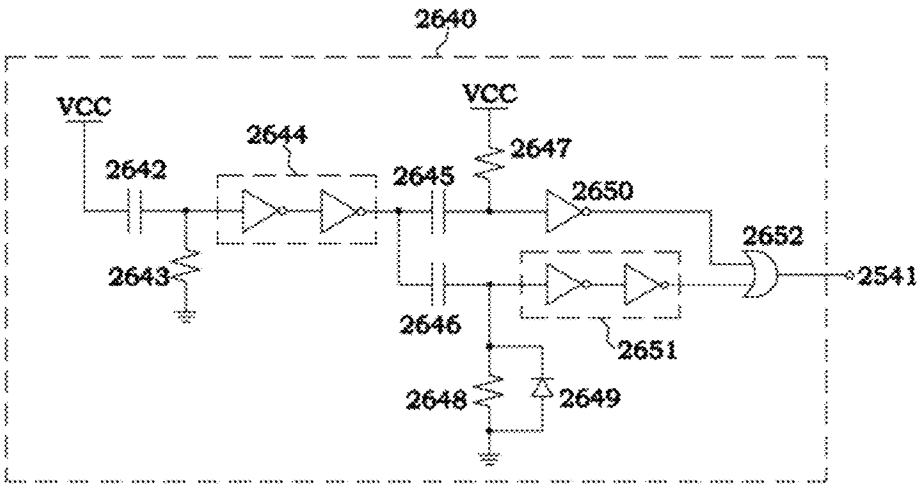

Fig. 15C

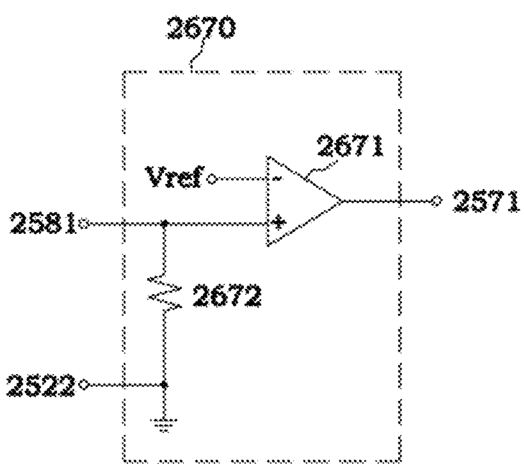

Fig. 15D

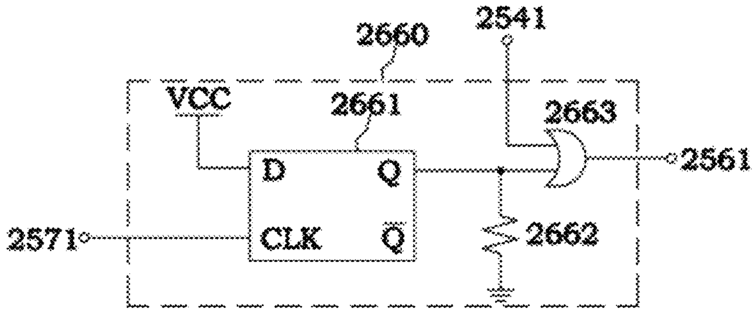

Fig. 15E

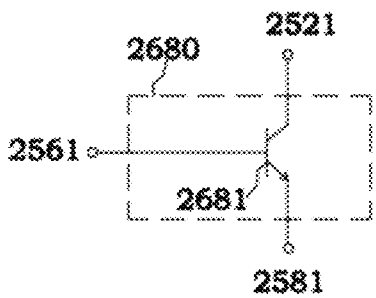

Fig. 15F

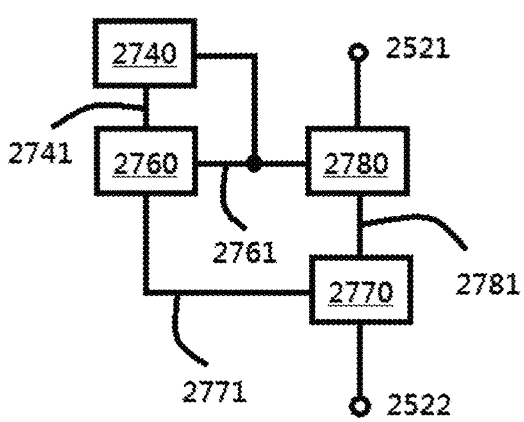

Fig. 15G

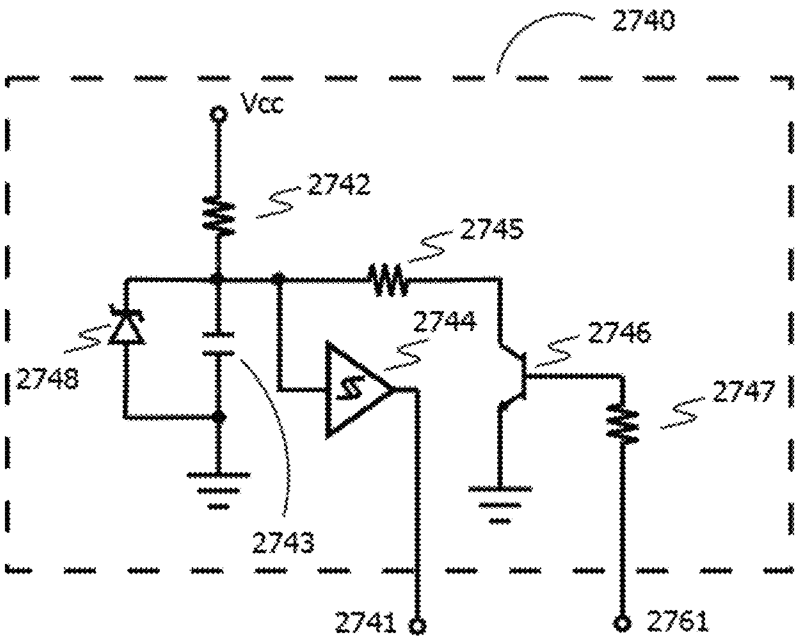

Fig. 15H

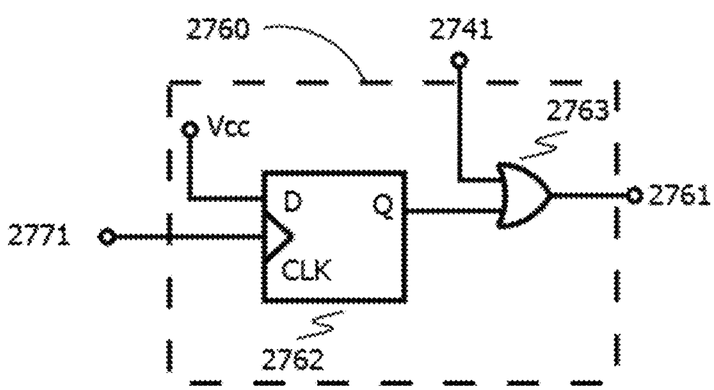

Fig. 15I

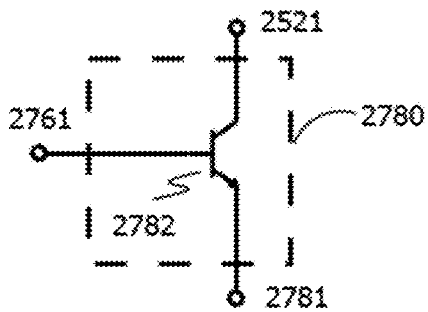

Fig. 15J

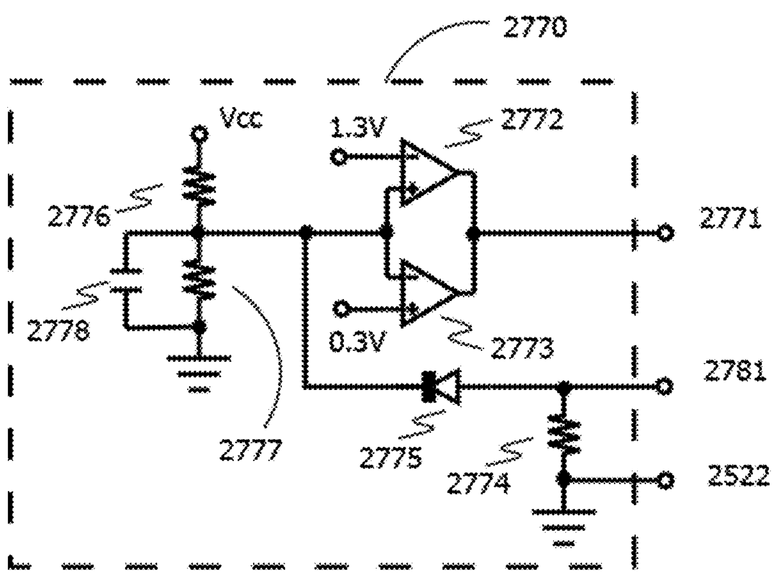

Fig. 15K

LED TUBE LAMP

RELATED APPLICATIONS

This application is a Continuation-In-Part application of U.S. patent application Ser. No. 15/210,989, filed on Jul. 15, 2016, which is a Continuation-In-Part application of U.S. patent application Ser. No. 15/066,645, filed on Mar. 10, 2016, which is a Continuation-In-Part application of U.S. patent application Ser. No. 14/865,387, filed on Sep. 25, 2015, the disclosure of each of which is incorporated in its entirety by reference herein. U.S. patent application Ser. No. 14/865,387, filed on Sep. 25, 2015 claims priority under 35 U.S.C. 119(e) to Chinese Patent Applications No.: CN 201410507660.9 filed on 2014 Sep. 28; CN 201410508899.8 filed on 2014 Sep. 28; CN 201410623355.6 filed on 2014 Nov. 6; CN 201410734425.5 filed on 2014 Dec. 5; CN 201510075925.7 filed on 2015 Feb. 12; CN 201510104823.3 filed on 2015 Mar. 10; CN 201510134586.5 filed on 2015 Mar. 26; CN 201510133689.x filed on 2015 Mar. 25; CN 201510136796.8 filed on 2015 Mar. 27; CN 201510155807.7 filed on 2015 Apr. 3; CN 201510173861.4 filed on 2015 Apr. 14; CN 201510193980.6 filed on 2015 Apr. 22; CN 201510372375.5 filed on 2015 Jun. 26; CN 201510259151.3 filed on 2015 May 19; CN 201510268927.8 filed on 2015 May 22; CN 201510284720.x filed on 2015 May 29; CN 201510338027.6 filed on 2015 Jun. 17; CN 201510315636.x filed on 2015 Jun. 10; CN 201510373492.3 filed on 2015 Jun. 26; CN 201510364735.7 filed on 2015 Jun. 26; CN 201510378322.4 filed on 2015 Jun. 29; CN 201510391910.1 filed on 2015 Jul. 2; CN 201510406595.5 filed on 2015 Jul. 10; CN 201510482944.1 filed on 2015 Aug. 7; CN 201510486115.0 filed on 2015 Aug. 8; CN 201510428680.1 filed on 2015 Jul. 20; CN 201510483475.5 filed on 2015 Aug. 8; CN 201510555543.4 filed on 2015 Sep. 2; CN 201510557717.0 filed on 2015 Sep. 6; CN 201510595173.7 filed on 2015 Sep. 18, the disclosures of each of which are incorporated herein in their entirety by reference.

In addition, U.S. patent application Ser. No. 15/066,645, from which U.S. patent application Ser. No. 15/210,989 claims priority as a Continuation-In-Part also claims priority under 35 U.S.C. 119(e) to Chinese Patent Applications Nos.: CN 201510530110.3 filed on 2015 Aug. 26; CN 201510499512.1 filed on 2015 Aug. 14; CN 201510448220.5 filed on 2015 Jul. 27; CN 201510645134.3 filed on 2015 Oct. 8; and CN 201510680883.x filed on 2015 Oct. 20, the disclosures of each of which are incorporated herein in their entirety by reference.

U.S. patent application Ser. No. 15/210,989 is also a Continuation-In-Part application of U.S. patent application Ser. No. 15/205,011, filed on Jul. 8, 2016, the disclosure of which is incorporated in its entirety by reference herein, which is a Continuation-In-Part application of U.S. patent application Ser. No. 15/150,458, filed on May 10, 2016, the disclosure of which is incorporated in its entirety by reference herein, which is a Continuation-In-Part application of U.S. patent application Ser. No. 14/865,387, filed on Sep. 25, 2015, which claims priority under 35 U.S.C. 119(e) to the following Chinese Patent Applications filed in the Chinese Patent Office: CN 201410507660.9 filed on 2014 Sep. 28; CN 201410508899.8 filed on 2014 Sep. 28; CN 201410623355.6 filed on 2014 Nov. 6; CN 201410734425.5 filed on 2014 Dec. 5; CN 201510075925.7 filed on 2015 Feb. 12; CN 201510104823.3 filed on 2015 Mar. 10; CN 201510134586.5 filed on 2015 Mar. 26; CN

201510133689.x filed on 2015 Mar. 25; CN 201510136796.8 filed on 2015 Mar. 27; CN 201510173861.4 filed on 2015 Apr. 14; CN 201510155807.7 filed on 2015 Apr. 3; CN 201510193980.6 filed on 2015 Apr. 22; CN 201510372375.5 filed on 2015 Jun. 26; CN 201510259151.3 filed on 2015 May 19; CN 201510268927.8 filed on 2015 May 22; CN 201510284720.x filed on 2015 May 29; CN 201510338027.6 filed on 2015 Jun. 17; CN 201510315636.x filed on 2015 Jun. 10; CN 201510373492.3 filed on 2015 Jun. 26; CN 201510364735.7 filed on 2015 Jun. 26; CN 201510378322.4 filed on 2015 Jun. 29; CN 201510391910.1 filed on 2015 Jul. 2; CN 201510406595.5 filed on 2015 Jul. 10; CN 201510482944.1 filed on 2015 Aug. 7; CN 201510486115.0 filed on 2015 Aug. 8; CN 201510428680.1 filed on 2015 Jul. 20; CN 201510483475.5 filed on 2015 Aug. 8; CN 201510555543.4 filed on 2015 Sep. 2; CN 201510557717.0 filed on 2015 Sep. 6; and CN 201510595173.7 filed on 2015 Sep. 18, the disclosures of which U.S. and Chinese patent applications are incorporated herein by reference in their entirety. U.S. patent application Ser. No. 15/150,458, filed on 2016 May 10 is also a Continuation-In-Part application of U.S. patent application Ser. No. 14/699,138, filed on 2015 Apr. 29, which claims priority under 35 U.S.C. 119(e) to Chinese Patent Application No. CN 201420602526.2, filed on 2014 Oct. 17.

In addition, U.S. patent application Ser. No. 15/205,011, from which U.S. patent application Ser. No. 15/210,989 claims priority as a Continuation-in-Part also claims priority under 35 U.S.C. 119(e) to Chinese Patent Application Nos.: CN 201610327806.0, filed on May 18, 2016; CN 201620089157.0, filed on Jan. 28, 2016; and CN 201610420790.8, filed on Jun. 14, 2016, the disclosures of each of which are incorporated herein in their entirety by reference.

In addition, U.S. patent application Ser. No. 15/210,989 also claims priority under 35 U.S.C. 119(e) to Chinese Patent Application Nos.: CN 201510848766.X, filed on Nov. 27, 2015; CN 201510903680.2, filed on Dec. 9, 2015; CN 201610132513.7, filed on Mar. 9, 2016; CN 201610142140.1, filed on Mar. 14, 2016; and CN 201610452437.8, filed on Jun. 20, 2016, the disclosures of each of which are incorporated herein in their entirety by reference. In addition, U.S. patent application Ser. No. 15/210,989 also claims priority under 35 U.S.C. 119(e) to Chinese Patent Application Nos.: CN 201510530110.3, filed on Aug. 26, 2015; CN 201510499512.1, filed on Aug. 14, 2015; CN 201510617370.4, filed on Sep. 25, 2015; CN 201510645134.3, filed on Oct. 8, 2015; CN 201510716899.1, filed on Oct. 29, 2015; CN 201510726365.7, filed on Oct. 30, 2015; CN 201510868263.9, filed on Dec. 2, 2015; CN 201610044148.4, filed on Jan. 22, 2016; CN 201610051691.7, filed on Jan. 26, 2016; CN 201610085895.2, filed on Feb. 15, 2016; CN 201610087627.4, filed on Feb. 16, 2016; CN201610281812.7, filed on Apr. 29, 2016; CN 201510705222.8, filed on Oct. 27, 2015; CN 201510726484.2, filed on Oct. 30, 2015; CN 201610050944.9, filed on Jan. 26, 2016; CN 201610098424.5, filed on Feb. 23, 2016; and CN 201610120993.5, filed on Mar. 3, 2016, the disclosures of each of which are incorporated herein by reference in their entirety.

In addition, this application claims priority under 35 U.S.C. 119(e) to Chinese Patent Application No.: CN

201610876593.7, filed on Oct. 8, 2016, the entire contents of which are incorporated herein by reference.

TECHNICAL FIELD

The disclosed embodiments relate to the features of light emitting diode (LED) lighting. More particularly, the disclosed embodiments describe various improvements for LED tube lamps.

BACKGROUND

LED lighting technology is rapidly developing to replace traditional incandescent and fluorescent lighting. LED tube lamps are mercury-free in comparison with fluorescent tube lamps that need to be filled with inert gas and mercury. Thus, it is not surprising that LED tube lamps are becoming a highly desired illumination option among different available lighting systems used in homes and workplaces, which used to be dominated by traditional lighting options such as compact fluorescent light bulbs (CFLs) and fluorescent tube lamps. Benefits of LED tube lamps include improved durability and longevity and far less energy consumption. Therefore, when taking into account all factors, they would typically be considered as a cost effective lighting option.

Typical LED tube lamps have a lamp tube, a circuit board disposed inside the lamp tube with light sources being mounted on the circuit board, and end caps accompanying a power supply provided at two ends of the lamp tube with the electricity from the power supply transmitting to the light sources through the circuit board. However, existing LED tube lamps have certain drawbacks. For example, the typical circuit board is rigid and allows the entire lamp tube to maintain a straight tube configuration when the lamp tube is partially ruptured or broken, and this gives the user a false impression that the LED tube lamp remains usable and is likely to cause the user to be electrically shocked upon handling or installation of the LED tube lamp.

Conventional circuit design of LED tube lamps typically doesn't provide suitable solutions for complying with relevant certification standards. For example, since there are usually no electronic components in a fluorescent lamp, it's fairly easy for a fluorescent lamp to be certified under EMI (electromagnetic interference) standards and safety standards for lighting equipment as provided by Underwriters Laboratories (UL). However, there are a considerable number of electronic components in an LED tube lamp, and therefore consideration of the impacts caused by the layout (structure) of the electronic components is important, resulting in difficulties in complying with such standards.

Further, the driving of an LED uses a DC driving signal, but the driving signal for a fluorescent lamp is a low-frequency, low-voltage AC signal as provided by an AC powerline, a high-frequency, high-voltage AC signal provided by a ballast, or even a DC signal provided by a battery for emergency lighting applications. Since the voltages and frequency spectrums of these types of signals differ significantly, simply performing a rectification to produce the required DC driving signal in an LED tube lamp may not achieve the LED tube lamp's compatibility with traditional driving systems of a fluorescent lamp.

Moreover, when an LED tube lamp has an architecture with dual-end power supply and one end cap thereof is inserted into a lamp socket but the other is not, an electric shock situation could take place for the user touching the metal or conductive part of the end cap which has not been inserted into the lamp socket.

Currently, LED tube lamps used to replace traditional fluorescent lighting devices can be primarily categorized into two types. One is for ballast-compatible LED tube lamps, e.g., T-LED lamp, which directly replaces fluorescent tube lamps without changing any circuit on the lighting device; and the other one is for ballast by-pass LED tube lamps, which omit traditional ballast on their circuit and directly connect the commercial electricity to the LED tube lamp. The latter LED tube lamp is suitable for the new surroundings in fixtures with new driving circuits and LED tube lamps.

SUMMARY

It's specially noted that the present disclosure may actually include one or more inventions claimed currently or not yet claimed, and for avoiding confusion due to unnecessarily distinguishing between those possible inventions at the stage of preparing the specification, the possible plurality of inventions herein may be collectively referred to as "the (present) invention" herein.

Various embodiments are summarized in this section, and may be described with respect to the "present invention," which terminology is used to describe certain presently disclosed embodiments, whether claimed or not, and is not necessarily an exhaustive description of all possible embodiments, but rather is merely a summary of certain embodiments. Certain of the embodiments described below as various aspects of the "present invention" can be combined in different manners to form an LED tube lamp or a portion thereof.

The present disclosure provides a novel LED tube lamp, and aspects thereof.

According to certain embodiments, an installation detection circuit configured in the LED tube lamp configured to receive an external driving signal is disclosed. The installation detection circuit includes: a pulse generating circuit configured to output one or more pulse signals; wherein the installation detection circuit is configured to detect during one or more pulse signals whether the LED tube lamp is properly installed on a lamp socket, based on detecting a signal generated from the external driving signal; and a switch circuit coupled to the pulse generating circuit, wherein the one or more pulse signals control turning on and off of the switch circuit; wherein the installation detection circuit is further configured to: when it is detected during one or more pulse signals that the LED tube lamp is not properly installed on the lamp socket, control the switch circuit to remain in an off state to cause a power loop of the LED tube lamp to be open; and when it is detected during one or more pulse signals that the LED tube lamp is properly installed on the lamp socket, control the switch circuit to remain in a conducting state to cause the power loop of the LED tube lamp to maintain conducting state.

According to certain embodiments, an installation detection circuit configured in a light-emitting diode (LED) tube lamp is disclosed. The installation detection circuit includes: means for generating one or more pulse signals; means for detecting during one or more pulse signals whether the LED tube lamp is properly installed on a lamp socket; and a switch circuit coupled to the means for generating one or more pulse signals, wherein the one or more pulse signals control turning on and off of the switch circuit; wherein the installation detection circuit is further configured to: when it is detected during the one or more pulse signals that the LED tube lamp is not properly installed on the lamp socket, control the switch circuit to remain in an off state to cause a power loop of the LED tube lamp to be open; and when it is detected during the one or more pulse signals that the LED tube lamp is properly installed on the lamp socket, control the switch circuit to remain in a conducting state to cause the power loop of the LED tube lamp to maintain a conducting state.

According to certain embodiments, a detection method adopted by a light-emitting device (LED) tube lamp for preventing a user from electric shock when the LED tube lamp is being installed on a lamp socket is disclosed. The detection method includes: when at least one end of the LED tube lamp is installed on the lamp socket, generating one or more pulse signals by a pulse generating circuit, wherein the pulse generating circuit is configured in the LED tube lamp; detecting a sampling signal on a power loop of the LED tube lamp by a detection determining circuit, to detect during the one or more pulse signals whether the other end of the LED tube lamp is properly installed on the lamp socket; receiving the one or more pulse signals through a detection result latching circuit by a switch circuit, wherein the switch circuit is on the power loop; and comparing the sampling signal with a predefined signal, wherein during the one or more pulse signals when the sampling signal is smaller than the predefined signal, the detection method further comprises: controlling the switch circuit to remain in an off state to cause the power loop of the LED tube lamp to be open.

BRIEF DESCRIPTION OF THE FIGURES

FIG. **1** is a plane cross-sectional view schematically illustrating an LED tube lamp including an LED light strip that is a bendable circuit sheet with ends thereof passing across the transition region of the lamp tube of the LED tube lamp to be connected to a power supply according to some exemplary embodiments;

FIG. **2** is a plane cross-sectional view schematically illustrating a bi-layered structure of a bendable circuit sheet of an LED light strip of an LED tube lamp according to some exemplary embodiments;

FIG. **3**A is a perspective view schematically illustrating a soldering pad of a bendable circuit sheet of an LED light strip for a solder connection with a power supply of an LED tube lamp according to some exemplary embodiments;

FIG. **3**B is a block diagram illustrating leads that are disposed between two end caps of an LED tube lamp according to some exemplary embodiments;

FIG. **4**A is a perspective view of a bendable circuit sheet and a printed circuit board of a power supply soldered to each other in accordance with an exemplary embodiment;

FIGS. **4**B, **4**C, and **4**D are diagrams of a soldering process of the bendable circuit sheet and the printed circuit board of the power supply of FIG. **4**A in accordance with an exemplary embodiment;

FIG. **5** is a perspective view schematically illustrating a circuit board assembly composed of a bendable circuit sheet of an LED light strip and a printed circuit board of a power supply according to some exemplary embodiments;

FIG. **6** is a perspective view schematically illustrating another arrangement of a circuit board assembly, according to some exemplary embodiments;

FIG. **7** is a perspective view schematically illustrating a bendable circuit sheet of an LED light strip formed with two conductive wiring layers according to some exemplary embodiments;

FIG. **8**A is a block diagram of an exemplary power supply system for an LED tube lamp according to some exemplary embodiments;

FIG. **8**B is a block diagram of an exemplary power supply system for an LED tube lamp according to some exemplary embodiments;

FIG. **8**C is a block diagram of an exemplary LED lamp according to some exemplary embodiments;

FIG. **9** is a schematic diagram of a rectifying circuit according to some exemplary embodiments;

FIGS. **10**A-**10**C are block diagrams of exemplary filtering circuits according to some exemplary embodiments;

FIGS. **11**A-**11**B are schematic diagrams of exemplary LED modules according to some exemplary embodiments;

FIGS. **11**C-**11**E are plan views of a circuit layout of an LED module according to some exemplary embodiments;

FIG. **12**A is a block diagram of an exemplary power supply module in an LED lamp according to some exemplary embodiments;

FIG. **12**B is a block diagram of a driving circuit according to some exemplary embodiments;

FIGS. **12**C-**12**F are schematic diagrams of exemplary driving circuits according to some exemplary embodiments;

FIG. **13**A is a block diagram of an exemplary power supply module in an LED tube lamp according to some exemplary embodiments;

FIG. **13**B is a schematic diagram of an over-voltage protection (OVP) circuit according to some exemplary embodiments;

FIG. **14**A is a block diagram of an exemplary power supply module in an LED tube lamp according to some exemplary embodiments;

FIG. **14**B is a block diagram of an exemplary power supply module in an LED tube lamp according to some exemplary embodiments;

FIG. **14**C is a schematic diagram of an auxiliary power module according to some exemplary embodiments;

FIG. **15**A is a block diagram of an LED tube lamp according to some exemplary embodiments;

FIG. **15**B is a block diagram of an installation detection module according to some exemplary embodiments;

FIG. **15**C is a schematic detection pulse generating module according to some exemplary embodiments;

FIG. **15**D is a schematic detection determining circuit according to some exemplary embodiments;

FIG. **15**E is a schematic detection result latching circuit according to some exemplary embodiments;

FIG. **15**F is a schematic switch circuit according to some exemplary embodiments;

FIG. **15**G is a block diagram of an installation detection module according to some exemplary embodiments;

FIG. **15**H is a schematic detection pulse generating module according to some exemplary embodiments;

FIG. **15**I is a schematic detection result latching circuit according to some exemplary embodiments;

FIG. **15**J is a schematic switch circuit according to some exemplary embodiments; and

FIG. **15**K is a schematic detection determining circuit according to some exemplary embodiments.

DETAILED DESCRIPTION OF THE EMBODIMENTS

The present disclosure provides a novel LED tube lamp. The present disclosure will now be described in the following embodiments with reference to the drawings. The following descriptions of various embodiments of this invention are presented herein for purpose of illustration and giving examples only. It is not intended to be exhaustive or to be limited to the precise form disclosed. These example embodiments are just that—examples—and many implementations and variations are possible that do not require the details provided herein. It should also be emphasized that the disclosure provides details of alternative examples, but such listing of alternatives is not exhaustive. Furthermore, any consistency of detail between various examples should not be interpreted as requiring such detail—it is impracticable to list every possible variation for every feature described herein. The language of the claims should be referenced in determining the requirements of the invention.

In the drawings, the size and relative sizes of components may be exaggerated for clarity. Like numbers refer to like elements throughout.

The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the invention. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items and may be abbreviated as "/".

It will be understood that, although the terms first, second, third etc. may be used herein to describe various elements, components, regions, layers, or steps, these elements, components, regions, layers, and/or steps should not be limited by these terms. Unless the context indicates otherwise, these terms are only used to distinguish one element, component, region, layer, or step from another element, component, region, layer, or step, for example as a naming convention. Thus, a first element, component, region, layer, or step discussed below in one section of the specification could be termed a second element, component, region, layer, or step in another section of the specification or in the claims without departing from the teachings of the present invention. In addition, in certain cases, even if a term is not described using "first," "second," etc., in the specification, it may still be referred to as "first" or "second" in a claim in order to distinguish different claimed elements from each other.

It will be further understood that the terms "comprises" and/or "comprising," or "includes" and/or "including" when used in this specification, specify the presence of stated features, regions, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, regions, integers, steps, operations, elements, components, and/or groups thereof.

It will be understood that when an element is referred to as being "connected" or "coupled" to or "on" another element, it can be directly connected or coupled to or on the other element or intervening elements may be present. In contrast, when an element is referred to as being "directly connected" or "directly coupled" to another element, there are no intervening elements present. Other words used to describe the relationship between elements should be interpreted in a like fashion (e.g., "between" versus "directly between," "adjacent" versus "directly adjacent," etc.). However, the term "contact," as used herein refers to direct connection (i.e., touching) unless the context indicates otherwise.

Embodiments described herein will be described referring to plane views and/or cross-sectional views by way of ideal schematic views. Accordingly, the exemplary views may be modified depending on manufacturing technologies and/or tolerances. Therefore, the disclosed embodiments are not limited to those shown in the views, but include modifications in configuration formed on the basis of manufacturing processes. Therefore, regions exemplified in figures may have schematic properties, and shapes of regions shown in figures may exemplify specific shapes of regions of elements to which aspects of the invention are not limited.

Spatially relative terms, such as "beneath," "below," "lower," "above," "upper" and the like, may be used herein for ease of description to describe one element's or feature's relationship to another element(s) or feature(s) as illustrated in the figures. It will be understood that the spatially relative terms are intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. For example, if the device in the figures is turned over, elements described as "below" or "beneath" other elements or features would then be oriented "above" the other elements or features. Thus, the term "below" can encompass both an orientation of above and below. The device may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein interpreted accordingly.

Terms such as "same," "equal," "planar," or "coplanar," as used herein when referring to orientation, layout, location, shapes, sizes, amounts, or other measures do not necessarily mean an exactly identical orientation, layout, location, shape, size, amount, or other measure, but are intended to encompass nearly identical orientation, layout, location, shapes, sizes, amounts, or other measures within acceptable variations that may occur, for example, due to manufacturing processes. The term "substantially" may be used herein to emphasize this meaning, unless the context or other statements indicate otherwise. For example, items described as "substantially the same," "substantially equal," or "substantially planar," may be exactly the same, equal, or planar, or may be the same, equal, or planar within acceptable variations that may occur, for example, due to manufacturing processes.

Terms such as "about" or "approximately" may reflect sizes, orientations, or layouts that vary only in a small relative manner, and/or in a way that does not significantly alter the operation, functionality, or structure of certain elements. For example, a range from "about 0.1 to about 1" may encompass a range such as a 0%-5% deviation around 0.1 and a 0% to 5% deviation around 1, especially if such deviation maintains the same effect as the listed range.

Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this disclosure belongs. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and/or the present application, and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

As used herein, items described as being "electrically connected" are configured such that an electrical signal can be passed from one item to the other. Therefore, a passive electrically conductive component (e.g., a wire, pad, internal electrical line, etc.) physically connected to a passive electrically insulative component (e.g., a prepreg layer of a printed circuit board, an electrically insulative adhesive connecting two devices, an electrically insulative underfill or mold layer, etc.) is not electrically connected to that component. Moreover, items that are "directly electrically connected," to each other are electrically connected through one or more passive elements, such as, for example, wires, pads, internal electrical lines, resistors, etc. As such, directly electrically connected components do not include components electrically connected through active elements, such as transistors or diodes. Directly electrically connected elements may be directly physically connected and directly electrically connected.

Components described as thermally connected or in thermal communication are arranged such that heat will follow a path between the components to allow the heat to transfer from the first component to the second component. Simply because two components are part of the same device or board does not make them thermally connected. In general, components which are heat-conductive and directly connected to other heat-conductive or heat-generating components (or connected to those components through intermediate heat-conductive components or in such close proximity as to permit a substantial transfer of heat) will be described as thermally connected to those components, or in thermal communication with those components. On the contrary, two components with heat-insulative materials therebetween, which materials significantly prevent heat transfer between the two components, or only allow for incidental heat transfer, are not described as thermally connected or in thermal communication with each other. The terms "heat-conductive" or "thermally-conductive" do not apply to any material that provides incidental heat conduction, but are intended to refer to materials that are typically known as good heat conductors or known to have utility for transferring heat, or components having similar heat conducting properties as those materials.

Embodiments may be described, and illustrated in the drawings, in terms of functional blocks, units and/or modules. Those skilled in the art will appreciate that these blocks, units and/or modules are physically implemented by electronic (or optical) circuits such as logic circuits, discrete components, analog circuits, hard-wired circuits, memory elements, wiring connections, and the like, which may be formed using semiconductor-based fabrication techniques or other manufacturing technologies. In the case of the blocks, units and/or modules being implemented by microprocessors or similar, they may be programmed using software (e.g., microcode) to perform various functions discussed herein and may optionally be driven by firmware and/or software. Alternatively, each block, unit and/or module may be implemented by dedicated hardware, or as a combination of dedicated hardware to perform some functions and a processor (e.g., one or more programmed microprocessors and associated circuitry) to perform other functions. Also, each block, unit and/or module of the embodiments may be physically separated into two or more interacting and discrete blocks, units and/or modules. Further, the blocks, units and/or modules of the various embodiments may be physically combined into more complex blocks, units and/or modules.

If any terms in this application conflict with terms used in any application(s) from which this application claims priority, or terms incorporated by reference into this application or the application(s) from which this application claims priority, a construction based on the terms as used or defined in this application should be applied.

Applicant's prior U.S. patent application Ser. No. 14/724,840 (US PGPUb No. 2016/0091156, the disclosure of which is incorporated herein in its entirety by reference), as an illustrated example, has addressed certain issues associated with the occurrence of electric shock in using a conventional LED lamp by providing a bendable circuit sheet. Some of the embodiments disclosed in U.S. patent application Ser. No. 14/724,840 can be combined with one or more of the example embodiments disclosed herein to further reduce the occurrence of electric shock in using an LED lamp.

Referring to FIG. **1**, an LED tube lamp may include an LED light strip **2**. In certain embodiments, the LED light strip **2** may be formed from a bendable circuit sheet, for example that may be flexible. As described further below, the bendable circuit sheet, also described as a bendable circuit board, or a flexible or non-rigid tape. The bendable circuit sheet may have ends thereof passing across a transition region of the lamp tube of the LED tube lamp to be connected to a power supply **5**. In some embodiments, the ends of the bendable circuit sheet may be connected to a power supply in an end cap of the LED tube lamp. For example, the ends may be connected in a manner such that a portion of the bendable circuit sheet is bent away from the lamp tube and passes through the transition region where a lamp tube narrows, and such that the bendable circuit sheet vertically overlaps part of a power supply within an end cap of the LED tube lamp.

Referring to FIG. **2**, to form an LED light strip **2**, a bendable circuit sheet includes a wiring layer **2***a* with conductive effect. An LED light source **202** is disposed on the wiring layer **2***a* and is electrically connected to the power supply through the wiring layer **2***a*. Though only one LED light source **202** is shown in FIG. **2**, a plurality of LED light sources **202**, as shown in FIG. **1**, may be arranged on the LED light strip **2**. For example, light sources **202** may be arranged in one or more rows extending along a length direction of the LED light strip **2**, which may extend along a length direction of the lamp tube as illustrated in FIG. **1**. The wiring layer with conductive effect, in this specification, is also referred to as a conductive layer. Referring to FIG. **2** again, in one embodiment, the LED light strip **2** includes a bendable circuit sheet having a conductive wiring layer **2***a* and a dielectric layer **2***b* that are arranged in a stacked manner. In some embodiments, the wiring layer **2***a* and the dielectric layer **2***b* may have the same areas or the area of the wiring layer **2***a* may slightly be smaller than that of the dielectric layer **2***b*. The LED light source **202** is disposed on one surface of the wiring layer **2***a*, the dielectric layer **2***b* is disposed on the other surface of the wiring layer **2***a* that is away from the LED light sources **202** (e.g., a second, opposite surface from the first surface on which the LED light source **202** is disposed). The wiring layer **2***a* is electrically connected to a power supply **5** (as shown in FIG. **1**) to carry direct current (DC) signals. In some embodiments, the surface of the dielectric layer **2***b* away from the wiring layer **2***a* (e.g., a second surface of the dielectric layer **2***b* opposite a first surface facing the wiring layer **2***a*) is fixed to an inner circumferential surface of a lamp tube, for example, by means of an adhesive sheet **4**. The portion of the dielectric layer **2***b* fixed to the inner circumferential surface of the lamp tube **1** may substantially conform to the shape of the inner circumferential surface of the lamp tube **1**. The wiring layer **2***a* can be a metal layer or a power supply layer including wires such as copper wires.

A power supply as described herein may include a circuit that converts or generates power based on a received voltage, in order to supply power to operate an LED module and the LED light sources **202** of the LED tube lamp. A power supply, as described in connection with power supply **5**, may be otherwise referred to as a power conversion module or circuit or a power module. A power conversion module or circuit, or power module, may supply or provide power from external signal(s), such as from an AC power line or from a ballast, to an LED module and the LED light sources **202**. For example, a power supply **5** may refer to a circuit that converts ac line voltage to dc voltage and supplies power to the LED or LED module. The power supply **5** may include one or more power components mounted thereon for converting and/or generating power.

In some example embodiments, the outer surface of the wiring layer **2***a* or the dielectric layer **2***b* may be covered with a circuit protective layer made of an ink with function of resisting soldering and increasing reflectivity. Alternatively, in other example embodiments, the dielectric layer may be omitted and the wiring layer may be directly bonded to the inner circumferential surface of the lamp tube, and the outer surface of the wiring layer **2***a* may be coated with the circuit protective layer. Whether the wiring layer **2***a* has a one-layered, or two-layered structure, the circuit protective layer may be adopted. In some embodiments, the circuit protective layer is disposed only on one side/surface of the LED light strip **2**, such as the surface having the LED light source **202**. In some embodiments, the bendable circuit sheet is a one-layered structure made of just one wiring layer **2***a*, or a two-layered structure made of one wiring layer **2***a* and one dielectric layer **2***b*, and thus is more bendable or flexible to curl when compared with the conventional three-layered flexible substrate (one dielectric layer sandwiched with two wiring layers). As a result, the bendable circuit sheet of the LED light strip **2** may be installed in a lamp tube with a customized shape or non-tubular shape, and fitly mounted to the inner surface of the lamp tube. A bendable circuit sheet closely mounted to the inner surface of the lamp tube is desirable in some cases. In addition, using fewer layers of the bendable circuit sheet improves the heat dissipation, lowering the material cost, and is more environmental friendly, and provides the opportunity to increase the flexible effect.

Nevertheless, the bendable circuit sheet is not limited to being one-layered or two-layered; in other embodiments, the bendable circuit sheet may include multiple layers of the wiring layers **2***a* and multiple layers of the dielectric layers **2***b*, in which the dielectric layers **2***b* and the wiring layers **2***a* are sequentially stacked in a staggered manner, respectively. These stacked layers may be between the outermost wiring layer **2***a* (with respect to the inner circumferential surface of the lamp tube), which has the LED light source **202** disposed thereon, and the inner circumferential surface of the lamp tube, and may be electrically connected to the power supply **5** (as shown in FIG. **1**.) Moreover, in some embodiments, the length of the bendable circuit sheet (e.g., the length along a surface of the bendable circuit sheet from one end of the circuit sheet to a second end of the circuit sheet) (or an axial projection of the length of the bendable circuit sheet) is greater than the length of the lamp tube (or an axial projection of the length of the lamp tube), or at least greater than a central portion of the lamp tube between two transition regions (e.g., where the circumference of the lamp tube narrows) on either end. For example, the length following along the contours of one surface of the bendable circuit sheet (e.g., a top surface of the circuit sheet) may be longer than the length from one terminal end to an opposite terminal end of the lamp tube. Also, a length along a straight line that extends in the same direction as the direction in which the lamp tube extends, from a first end of the bendable circuit sheet to a second, opposite end of the bendable circuit sheet, may be longer than the length along the same straight line of the lamp tube.

Referring to FIG. **7**, in one embodiment, an LED light strip **2** includes a bendable circuit sheet having in sequence a first wiring layer **2***a*, a dielectric layer **2***b*, and a second wiring layer **2***c*. In one example, the thickness of the second wiring layer **2***c* (e.g., in a direction in which the layers **2***a* through **2***c* are stacked) is greater than that of the first wiring layer **2***a*, and the length of the LED light strip **2** (or an axial projection of the length of the LED light strip **2**) is greater than that of a lamp tube **1**, or at least greater than a central portion of the lamp tube between two transition regions (e.g., where the circumference of the lamp tube narrows) on either end. The end region of the LED light strip **2** extending beyond the end portion of the lamp tube **1** without having a light source **202** disposed thereon is formed with two separate through holes **203** and **204** to respectively electrically communicate the first wiring layer **2***a* and the second wiring layer **2***c*. The through holes **203** and **204** are not in communication with each other to avoid short.

In this way, the greater thickness of the second wiring layer **2***c* allows the second wiring layer **2***c* to support the first wiring layer **2***a* and the dielectric layer **2***b*, and meanwhile allows the LED light strip **2** to be mounted onto the inner circumferential surface without being liable to shift or deform, and thus the yield rate of product can be improved. In addition, the first wiring layer **2***a* and the second wiring layer **2***c* are in electrical communication such that the circuit layout of the first wiring later **2***a* can be extended downward to the second wiring layer **2***c* to reach the circuit layout of the entire LED light strip **2**. Moreover, since the circuit layout becomes two-layered, the area of each single layer and therefore the width of the LED light strip **2** can be reduced such that more LED light strips **2** can be put on a production line to increase productivity.

Furthermore, in some embodiments, the first wiring layer **2***a* and the second wiring layer **2***c* of the end region of the LED light strip **2** that extends beyond the end portion of the lamp tube **1** without disposition of the light source **202** can be used to accomplish the circuit layout of a power supply module so that the power supply module can be directly disposed on the bendable circuit sheet of the LED light strip **2**.

In a case where two ends of the LED light strip **2** are detached from the inner surface of the lamp tube **1** and where the LED light strip **2** is connected to the power supply **5** via wire-bonding, certain movements in subsequent transportation are likely to cause the bonded wires to break. Therefore, a desirable option for the connection between the LED light strip **2** and the power supply **5** (as shown in FIG. **1**) could be soldering. Specifically, referring to FIG. **1**, the ends of the LED light strip **2** including the bendable circuit sheet are arranged to pass over the strengthened transition region of a lamp tube, and to be directly solder bonded to an output terminal of the power supply **5**. This may improve product quality by avoiding using wires and/or wire bonding. As discussed herein, a transition region of the lamp tube refers to regions outside a central portion of the lamp tube and inside terminal ends of the lamp tube. For example, a central portion of the lamp tube may have a constant diameter, and each transition region between the central portion and a terminal end of the lamp tube may have a changing diameter (e.g., at least part of the transition region may become more narrow moving in a direction from the central portion to the terminal end of the lamp tube).

Referring to FIG. **3**A, an output terminal of a printed circuit board of the power supply **5** may have soldering pads "a" (as shown in FIG. **1** as well) provided with an amount of solder (e.g., tin solder) with a thickness sufficient to later form a solder joint "g" (or a solder ball "g"). Correspondingly, the ends of the LED light strip **2** may have soldering pads "b" (as shown in FIG. **1** as well). The soldering pads "a" on the output terminal of the printed circuit board of the power supply **5** are soldered to the soldering pads "b" on the LED light strip **2** via the tin solder on the soldering pads "a".

The soldering pads "a" and the soldering pads "b" may be face to face during soldering such that the connection between the LED light strip **2** and the printed circuit board of the power supply **5** may be the firmest. However, this kind of soldering typically includes a thermo-compression head pressing on the rear surface of the LED light strip **2** and heating the tin solder, i.e., the LED light strip **2** intervenes between the thermo-compression head and the tin solder, and therefore may cause reliability problems. In some embodiments, a through hole may be formed in each of the soldering pads "b" on the LED light strip **2** to allow the soldering pads "b" to overlay the soldering pads "a" without being face-to-face (e.g., both soldering pads "a" and soldering pads "b" can have exposed surfaces that face the same direction) and the thermo-compression head directly presses tin solders on the soldering pads "a" on surface of the printed circuit board of the power supply **5** when the soldering pads "a" and the soldering pads "b" are vertically aligned. This example provides a simple process for manufacturing.

Referring again to FIG. **3**A, two ends of the LED light strip **2** detached from the inner surface of the lamp tube **1** (as shown in FIG. **7**) are formed as freely extending portions **21** (as shown in FIGS. **1** and **7** as well), while most of the LED light strip **2** is attached and secured to the inner surface of the lamp tube. One of the freely extending portions **21** has the soldering pads "b" as mentioned above. Upon assembling of the LED tube lamp, the freely extending end portions **21** along with the soldered connection of the printed circuit board of the power supply **5** and the LED light strip **2** would be coiled, curled up or deformed to be fittingly accommodated inside the lamp tube as shown in FIG. **1**. When the bendable circuit sheet of the LED light strip **2** includes in sequence the first wiring layer **2***a*, the dielectric layer **2***b*, and the second wiring layer **2***c* as shown in FIG. **7**, the freely extending end portions **21**, which are the end regions of the LED light strip **2** extending beyond the lamp tube without disposition of the light sources **202**, can be used to accomplish the connection between the first wiring layer **2***a* and the second wiring layer **2***c* and arrange the circuit layout of the power supply **5**. As described above, the freely extending portions **21** may be different from a fixed portion of the LED light strip **2** in that the fixed portion may conform to the shape of the inner surface of the lamp tube and may be fixed thereto, while the freely extending portion **21** may have a shape that does not conform to the shape of the lamp tube. As shown in FIG. **1**, the freely extending portion **21** may be bent away from the lamp tube. For example, there may be a space between an inner surface of the lamp tube and the freely extending portion **21**.

In designing the conductive pin or external connection terminal in the LED tube lamp, various arrangements of pins may be provided in one end or both ends of the LED tube lamp according to exemplary embodiments. For example, two pins may be provided in one end and no pins may be provided on the other end. Alternatively, in some embodiments, two pins in corresponding ends of two ends of the LED tube lamp, or four pins in corresponding ends of two ends of the LED tube lamp may be provided. When a dual-end power supply between two ends of the LED tube lamp is utilized to provide power to the LED tube lamp, at least one pin of each end of the LED tube lamp is used to receive the external driving signal from the power supply.

FIG. **3**B is a block diagram illustrating leads that are disposed between two end caps of an LED tube lamp according to some exemplary embodiments.

Referring to FIG. **3**B, in some embodiments, the LED tube lamp includes a lamp tube (not shown in FIG. **3**B), end caps (not shown in FIG. **3**B), a light strip **2**, short circuit boards **253** (also referred to as right end short circuit board **253** and left end short circuit board **253**) respectively provided at two ends of the lamp tube, and an inductive element **526**. Each of the lamp tube's two ends may have at least one pin or external connection terminal for receiving the external driving signal. The end caps are disposed respectively at the two ends of the lamp tube, and (at least partial electronic components of) the short circuit boards **253** shown as located respectively at the left and right ends of the lamp tube in FIG. **3**B may be disposed respectively in the end caps. The short circuit boards may be, for example, a rigid circuit board such as depicted in and described in connection with FIG. **1** and the various other rigid circuit boards described herein. For example, these circuit boards may include mounted thereon one or more power supply components for generating and/or converting power to be used to light the LED light sources on the light strip **2**. The light strip **2** is disposed in the lamp tube and includes an LED module, which includes an LED unit **632**.

For an LED tube lamp, such as an 8 ft. 42 W LED tube lamp, to receive a dual-end power supply between two ends of the LED tube lamp, two (partial) power-supply circuits (each having a power rating of e.g. 21 W) are typically disposed respectively in the two end caps of the lamp tube, and a lead (typically referred to as lead Line or Neutral) disposed between two end caps of the lamp tube (e.g., between two pins or external connection terminals at respective end caps of the lamp tube) and as an input signal line may be needed. The lead Line may be disposed along an LED light strip that may include, e.g., a bendable circuit sheet or flexible circuit board, for receiving and transmitting an external driving signal from the power supply. This lead Line is distinct from two leads typically referred to as LED+ and LED− that are respectively connected to a positive electrode and a negative electrode of an LED unit in the lamp tube. This lead Line is also distinct from a Ground lead which is disposed between respective ground terminals of the LED tube lamp. Because the lead Line is typically disposed along the light strip, and because parasitic capacitance(s) (e.g., about 200 pF) may be caused between the lead Line and the lead LED+ due to their close proximity to each other, some high frequency signals (not the intended frequency range of signal for supplying power to the LED module) passing through the lead LED+ will be reflected to the lead Line through the parasitic capacitance(s) and then can be detected there as undesirable EMI effects. The unfavorable EMI effects may lower or degrade the quality of power transmission in the LED tube lamp.

Again referring to FIG. **3**B, in some embodiments, the right and left short circuit boards **253** are electrically connected to the light strip **2**. In some embodiments, the electrical connection (such as through soldering or bond pad(s)) between the short circuit boards **253** and the light strip **2** may comprise a first terminal (denoted by "L"), a second terminal (denoted by "+" or "LED+"), a third terminal (denoted by "−" or "LED−"), and a fourth terminal (denoted by "GND" or "ground"). The light strip **2** includes the first through fourth terminals at a first end of the light strip **2** adjacent to the right end short circuit board **253** near one end cap of the lamp tube and includes the first through fourth terminals at a second end, opposite to the first end, of the light strip **2** adjacent to the left end short circuit board **253** near the other end cap of the lamp tube. The right end short circuit board **253** also includes the first through fourth terminals to respectively connect to the first through fourth terminals of the light strip **2** at the first end of the light strip

2. The left end short circuit board **253** also includes the first through fourth terminals to respectively connect to the first through fourth terminals of the light strip **2** at the second end of the light strip **2**. For example, the first terminal L is utilized to connect a lead (typically referred to as Line or Neutral) for connecting both of the at least one pin of each of the two ends of the lamp tube; the second terminal LED+ is utilized to connect each of the short circuit boards **253** to the positive electrode of the LED unit **632** of the LED module included in the light strip **2**. The third terminal LED− is utilized to connect each of the short circuit boards **253** to the negative electrode of the LED unit **632** of the LED module included in the light strip **2**. The fourth terminal GND is utilized to connect to a reference potential. Preferably and typically, the reference potential is defined as the electrical potential of ground. Therefore, the fourth terminal is utilized for a grounding purpose of the power supply module of the LED tube lamp.

To address the undesirable EMI effects mentioned above caused by parasitic capacitance(s) between the lead Line and the lead LED+, inductive element **526** disposed in the Ground lead serves to reduce or prevent the EMI effects by blocking the forming of a complete circuit between the lead LED+ and the Ground lead for the high frequency signals mentioned above to pass through, since at these high frequencies inductive element **526** behaves like an open circuit. When the complete circuit is prevented or blocked by inductive element **526**, the high frequency signals will be prevented on the lead LED+ and therefore will not be reflected to the lead Line, thus preventing the undesirable EMI effects. In some embodiments, the inductive element **526** is connected between two of the fourth terminals respectively of the right end and left end short circuit boards **253** at the two ends of the lamp tube. In some embodiments, the inductive element **526** may comprise an inductor such as a choke inductor or a dual-inline-package inductor capable of achieving a function of eliminating or reducing the above-mentioned EMI effects of the lead ("Line") disposed along the light strip **2** between two of the first terminals ("L") respectively at two ends of the lamp tube. Therefore, this function can improve signal transmission (which may include transmissions through leads "L", "LED+", and "LED−") of the power supply in the LED tube lamp, and thus the qualities of the LED tube lamp. Therefore, the LED tube lamp comprising the inductive element **526** may effectively reduce EMI effects of the lead "L" or "Line". Moreover, such an LED tube lamp may further comprise an installation detection circuit or module, which is described below with reference to FIG. **15**, for detecting whether or not the LED tube lamp is properly installed on a lamp socket.

Referring to FIGS. **5** and **6**, in another embodiment, the LED light strip and the power supply may be connected by utilizing a circuit board assembly **25** configured with a power supply module **250** instead of solder bonding as described previously. The circuit board assembly **25** has a long circuit sheet **251** and a short circuit board **253** that are adhered to each other with the short circuit board **253** being adjacent to the side edge of the long circuit sheet **251**. The short circuit board **253** may be provided with the power supply module **250** to form the power supply. The short circuit board **253** is stiffer or more rigid than the long circuit sheet **251** to be able to support the power supply module **250**.

The long circuit sheet **251** may be the bendable circuit sheet of the LED light strip **2** including a wiring layer **2*a*** as shown in FIG. **2**. The wiring layer **2*a*** of the LED light strip **2** and the power supply module **250** may be electrically connected in various manners depending on the demand in practice. As shown in FIG. **5**, the power supply module **250** and the long circuit sheet **251** having the wiring layer **2*a*** on surface are on the same side of the short circuit board **253** such that the power supply module **250** is directly connected to the long circuit sheet **251**. As shown in FIG. **6**, alternatively, the power supply module **250** and the long circuit sheet **251** including the wiring layer **2*a*** on surface are on opposite sides of the short circuit board **253** such that the power supply module **250** is directly connected to the short circuit board **253** and indirectly connected to the wiring layer **2*a*** of the LED light strip **2** by way of the short circuit board **253**.

The power supply module **250** and power supply **5** described above may include various elements for providing power to the LED light strip **2**. For example, they may include power converters or other circuit elements for providing power to the LED light strip **2**.

FIG. **4**A is a perspective view of an exemplary bendable circuit sheet **200** and a printed circuit board **420** of a power supply **400** soldered to each other. FIG. **4**B to FIG. **4**D are diagrams illustrating an exemplary soldering process of the bendable circuit sheet **200** and the printed circuit board **420** of the power supply **400**. In an embodiment, the bendable circuit sheet **200** and the freely extending end portion have the same structure. The freely extending end portion are the portions of two opposite ends of the bendable circuit sheet **200** and are utilized for being connected to the printed circuit board **420**. The bendable circuit sheet **200** and the power supply **400** are electrically connected to each other by soldering. The bendable circuit sheet **200** comprises a circuit layer **200*a*** and a circuit protection layer **200*c*** over a side of the circuit layer **200*a***. Moreover, the bendable circuit sheet **200** comprises two opposite surfaces which are a first surface **2001** and a second surface **2002**. The first surface **2001** is the one on the circuit layer **200*a*** and away from the circuit protection layer **200*c***. The second surface **2002** is the other one on the circuit protection layer **200*c*** and away from the circuit layer **200*a***. Several LED light sources **202** are disposed on the first surface **2001** and are electrically connected to circuits of the circuit layer **200*a***. The circuit protection layer **200*c*** is made, for example, by polyimide (PI) having less thermal conductivity but being beneficial to protect the circuits. The first surface **2001** of the bendable circuit sheet **200** comprises soldering pads "b" (or referred as first soldering pads). Soldering material "g" can be placed on the soldering pads "b". In one embodiment, the bendable circuit sheet **200** further comprises a notch "f". The notch "f" is disposed on an edge of the end of the bendable circuit sheet **200** soldered to the printed circuit board **420** of the power supply **400**. In some embodiments instead of a notch, a hole near the edge of the end of the bendable circuit sheet **200** may be used, which may thus provide additional contact material between the printed circuit board **420** and the bendable circuit sheet **200**, thereby providing a stronger connection. The printed circuit board **420** comprises a power circuit layer **420*a*** and soldering pads "a". Moreover, the printed circuit board **420** comprises two opposite surfaces which are a first surface (or a top surface) **421** and a second surface (or a bottom surface) **422**. The second surface **422** is the one on the power circuit layer **420*a***. The soldering pads "a" are respectively disposed on the first surface **421** (those soldering pads "a" on the first surface **421** may be referred as second soldering pads) and the second surface **422** (those soldering pads "a" on the second surface **422** may be referred as third soldering pads). The soldering pads "a" on the first surface **421** are corresponding to those on the second surface **422**. Soldering material "g" can be placed on the soldering pad "a". In one embodiment, considering the stability of soldering and the optimization of automatic process, the bendable circuit sheet **200** is disposed below the printed circuit board **420** (the direction is referred to FIG. **4**B). For example, the first surface **2001** of the bendable circuit sheet **200** is connected to the second surface **422** of the printed circuit board **420**. Also, as shown, the soldering material "g" can contact, cover, and be soldered to a top surface of the bendable circuit sheet **200** (e.g., first surface **2001**), end side surfaces of soldering pads "a," soldering pad "b," and power circuit layer **420***a* formed at an edge of the printed circuit board **420**, and a top surface of soldering pad "a" at the top surface **421** of the printed circuit board **420**. In addition, the soldering material "g" can contact side surfaces of soldering pads "a," soldering pad "b," and power circuit layer **420***a* formed at a hole in the printed circuit board **420** and/or at a hole or notch in bendable circuit sheet **200**. The soldering material may therefore form a bump-shaped portion covering portions of the bendable circuit sheet **200** and the printed circuit board **420**, and a rod-shaped portion passing through the printed circuit board **420** and through a hole or notch in the bendable circuit sheet **200**. The two portions (e.g., bump-shaped portion and rod-shaped portion) may serve as a rivet, for maintaining a strong connection between the bendable circuit sheet **200** and the printed circuit board **420**.

As shown in FIG. **4**C and FIG. **4**D, in an exemplary soldering process of the bendable circuit sheet **200** and the printed circuit board **420**, the circuit protection layer **200***c* of the bendable circuit sheet **200** is placed on a supporting table **42** (i.e., the second surface **2002** of the bendable circuit sheet **200** contacts the supporting table **42**) in advance of soldering. The soldering pads "a" on the second surface **422** of the printed circuit board **420** contact the soldering pads "b" on the first surface **2001** of the bendable circuit sheet **200**. And then a heating head **41** presses on a portion of soldering material "g" where the bendable circuit sheet **200** and the printed circuit board **420** are soldered to each other. When soldering, the soldering pads "b" on the first surface **2001** of the bendable circuit sheet **200** contact the soldering pads "a" on the second surface **422** of the printed circuit board **420**, and the soldering pads "a" on the first surface **421** of the printed circuit board **420** contact the soldering material "g," which is pressed on by the heating head **41**. Under the circumstance, the heat from the heating head **41** can transmit through the soldering pads "a" on the first surface **421** of the printed circuit board **420** and the soldering pads "a" on the second surface **422** of the printed circuit board **420** to the soldering pads "b" on the first surface **2001** of the bendable circuit sheet **200**. The transmission of the heat between the heating heads **41** and the soldering pads "a" and "b" won't be affected by the circuit protection layer **200***c* which has relatively less thermal conductivity, since the circuit protection layer **200***c* is not between the heating head **41** and the circuit layer **200***a*. Consequently, the efficiency and stability regarding the connections and soldering process of the soldering pads "a" and "b" of the printed circuit board **420** and the bendable circuit sheet **200** can be improved.

As shown in the exemplary embodiment of FIG. **4**C, the printed circuit board **420** and the bendable circuit sheet **200** are firmly connected to each other by the soldering material "g". Components between the virtual line M and the virtual line N of FIG. **4**C from top to bottom are the soldering pads "a" on the first surface **421** of printed circuit board **420**, the power circuit layer **420***a*, the soldering pads "a" on the second surface **422** of printed circuit board **420**, the soldering pads "b" on the first surface **2001** of bendable circuit sheet **200**, the circuit layer **200***a* of the bendable circuit sheet **200**, and the circuit protection layer **200***c* of the bendable circuit sheet **200**. The connection of the printed circuit board **420** and the bendable circuit sheet **200** are firm and stable. The soldering material "g" may extend higher than the soldering pads "a" on the first surface **421** of printed circuit board **420** and may fill in other spaces, as described above.

In other embodiments, an additional circuit protection layer (e.g., PI layer) can be disposed over the first surface **2001** of the circuit layer **200***a*. For example, the circuit layer **200***a* may be sandwiched between two circuit protection layers, and therefore the first surface **2001** of the circuit layer **200***a* can be protected by the circuit protection layer. A part of the circuit layer **200***a* (the part having the soldering pads "b") is exposed for being connected to the soldering pads "a" of the printed circuit board **420**. Other parts of the circuit layer **200***a* are exposed by the additional circuit protection layer so they can connect to LED light sources **202**. Under these circumstances, a part of the bottom of each LED light source **202** contacts the circuit protection layer on the first surface **2001** of the circuit layer **200***a*, and another part of the bottom of the LED light source **202** contacts the circuit layer **200***a*.

According to the exemplary embodiments shown in FIG. **4**A to FIG. **4**D, the printed circuit board **420** comprises through holes "h" passing through the soldering pads "a". In an automatic soldering process, when the heating head **41** automatically presses the printed circuit board **420**, the soldering material "g" on the soldering pads "a" can be pushed into the through holes "h" by the heating head **41** accordingly. As a result, a soldered connection may be formed as shown in FIGS. **4**C and **4**D.

FIG. **8**A is a block diagram of a system including an LED tube lamp including a power supply module according to certain embodiments. Referring to FIG. **8**A, an alternating current (AC) power supply **508** is used to supply an AC supply signal, and may be an AC powerline with a voltage rating, for example, in 100-277V and a frequency rating, for example, of 50 Hz or 60 Hz. A lamp driving circuit **505** receives the AC supply signal from the AC power supply **508** and then converts it into an AC driving signal. The power supply module and power supply **508** described above may include various elements for providing power to the LED light strip **2**. For example, they may include power converters or other circuit elements for providing power to the LED light strip **2**. In some embodiments, the power supply **508** and the lamp driving circuit **505** are outside of the LED tube lamp. For example, the lamp driving circuit **505** may be part of a lamp socket or lamp holder into which the LED tube lamp is inserted. The lamp driving circuit **505** could be an electronic ballast and may be used to convert the signal of commercial electricity into high-frequency and high-voltage AC driving signal. The common types of electronic ballast, such as instant-start electronic ballast, program-start electronic ballast, and rapid-start electronic ballast, can be applied to the LED tube lamp. In some embodiments, the voltage of the AC driving signal is bigger than 300V and in some embodiments 400-700V with frequency being higher than 10 kHz and in some embodiments 20-50 kHz. An LED tube lamp **500** receives the AC driving signal from the lamp driving circuit **505** and is thus driven to emit light. In the present embodiment, the LED tube lamp **500** is in a driving environment in which it is power-supplied at its one end cap having two conductive pins **501** and **502**, which are used to receive the AC driving signal. The two pins **501** and **502** may be electrically coupled to, either directly or indirectly, the lamp driving circuit **505**.

In some embodiments, the lamp driving circuit **505** may be omitted and is therefore depicted by a dotted line. In certain embodiments, if the lamp driving circuit **505** is omitted, the AC power supply **508** is directly coupled to the pins **501** and **502**, which then receive the AC supply signal as the AC driving signal.

In some embodiments, the LED tube lamp may be power-supplied at its both end caps respectively having two conductive pins, which are coupled to the lamp driving circuit to concurrently receive the AC driving signal. However, in certain embodiments, referring to FIG. **8**B, each end cap of the LED tube lamp **500** could have only one conductive pin for receiving the AC driving signal. For example, it is not required to have two conductive pins used in each end cap for the purpose of passing electricity through the both ends of the LED tube lamp. Compared to FIG. **8**A, the conductive pins **501** and **502** in FIG. **8**B are correspondingly configured at the both end caps of the LED tube lamp **500**, and the AC power supply **508** and the lamp driving circuit **505** are the same as those mentioned above.

FIG. **8**C is a block diagram of an LED lamp according to one embodiment. Referring to FIG. **8**C, the power supply module of the LED lamp includes a rectifying circuit **510**, a filtering circuit **520**, and may further include some parts of an LED lighting module **530**. The rectifying circuit **510** is coupled to two pins **501** and **502** to receive and then rectify an external driving signal, so as to output a rectified signal at two rectifying output terminals **511** and **512**. In some embodiments, the external driving signal may be the AC driving signal or the AC supply signal described with reference to FIGS. **8**A and **8**B. In some embodiments, the external driving signal may be a direct current (DC) signal without altering the LED tube lamp. The filtering circuit **520** is coupled to the rectifying circuit for filtering the rectified signal to produce a filtered signal. For instance, the filtering circuit **520** is coupled to the rectifying circuit output terminals **511** and **512** to receive and then filter the rectified signal, so as to output a filtered signal at two filtering output terminals **521** and **522**. The LED lighting module **530** is coupled to the filtering circuit **520** to receive the filtered signal for emitting light. For instance, the LED lighting module **530** may include a circuit coupled to the filtering output terminals **521** and **522** to receive the filtered signal and thereby to drive an LED unit (not shown) in the LED lighting module **530** to emit light. Details of these operations are described below in accordance with certain embodiments.

Although there are two rectifying output terminals **511** and **512** and two filtering output terminals **521** and **522** in the embodiments of these Figs., in practice the number of ports or terminals for coupling between the rectifying circuit **510**, the filtering circuit **520**, and the LED lighting module **530** may be one or more depending on the needs of signal transmission between the circuits or devices.

In addition, the power supply module of the LED lamp described in FIG. **8**C, and embodiments of a power supply module of an LED lamp described below, may each be used in the LED tube lamp **500** in FIGS. **8**A and **8**B, and may instead be used in any other type of LED lighting structure having two conductive pins used to conduct power, such as LED light bulbs, personal area lights (PAL), plug-in LED lamps with different types of bases (such as types of PL-S, PL-D, PL-T, PL-L, etc.), etc. Further, the implementation for LED light bulbs may provide better effects on protecting

from electric shock as combining this invention and the structures disclosed in PCT patent application WO2016045631.

FIG. **9** is a schematic diagram of a rectifying circuit according to an embodiment. Referring to FIG. **9**, a rectifying circuit **610**, i.e. a bridge rectifier, includes four rectifying diodes **611**, **612**, **613**, and **614**, configured to full-wave rectify a received signal. The diode **611** has an anode connected to the output terminal **512**, and a cathode connected to the pin **502**. The diode **612** has an anode connected to the output terminal **512**, and a cathode connected to the pin **501**. The diode **613** has an anode connected to the pin **502**, and a cathode connected to the output terminal **511**. The diode **614** has an anode connected to the pin **501**, and a cathode connected to the output terminal **511**.

When the pins **501** and **502** receive an AC signal, the rectifying circuit **610** operates as follows. During the connected AC signal's positive half cycle, the AC signal is input through the pin **501**, the diode **614**, and the output terminal **511** in sequence, and later output through the output terminal **512**, the diode **611**, and the pin **502** in sequence. During the connected AC signal's negative half cycle, the AC signal is input through the pin **502**, the diode **613**, and the output terminal **511** in sequence, and later output through the output terminal **512**, the diode **612**, and the pin **501** in sequence. Therefore, during the connected AC signal's full cycle, the positive pole of the rectified signal produced by the rectifying circuit **610** keeps at the output terminal **511**, and the negative pole of the rectified signal remains at the output terminal **512**. Accordingly, the rectified signal produced or output by the rectifying circuit **610** is a full-wave rectified signal.

When the pins **501** and **502** are coupled to a DC power supply to receive a DC signal, the rectifying circuit **610** operates as follows. When the pin **501** is coupled to the positive end of the DC power supply and the pin **502** to the negative end of the DC power supply, the DC signal is input through the pin **501**, the diode **614**, and the output terminal **511** in sequence, and later output through the output terminal **512**, the diode **611**, and the pin **502** in sequence. When the pin **501** is coupled to the negative end of the DC power supply and the pin **502** to the positive end of the DC power supply, the DC signal is input through the pin **502**, the diode **613**, and the output terminal **511** in sequence, and later output through the output terminal **512**, the diode **612**, and the pin **501** in sequence. Therefore, no matter what the electrical polarity of the DC signal is between the pins **501** and **502**, the positive pole of the rectified signal produced by the rectifying circuit **610** keeps at the output terminal **511**, and the negative pole of the rectified signal remains at the output terminal **512**.

Therefore, the rectifying circuit **610** in this embodiment can output or produce a proper rectified signal regardless of whether the received input signal is an AC or DC signal.

FIG. **10**A is a block diagram of the filtering circuit according to an embodiment. A rectifying circuit **510** is shown in FIG. **10**A for illustrating its connection with other components, without intending a filtering circuit **520** to include the rectifying circuit **510**. Referring to FIG. **10**A, the filtering circuit **520** includes a filtering unit **523** coupled to two rectifying output terminals **511** and **512** to receive and to filter out ripples of a rectified signal from the rectifying circuit **510**. Accordingly, the waveform of a filtered signal is smoother than that of the rectified signal. The filtering circuit **520** may further include another filtering unit **524** coupled between a rectifying circuit and a pin correspondingly, for example, between the rectifying circuit **510** and the pin **501**, the rectifying circuit **510** and the pin **502**, the rectifying circuit **540** and the pin **503**, and/or the rectifying circuit **540** and the pin **504**. The filtering unit **524** is used to filter a specific frequency, for example, to filter out a specific frequency of an external driving signal. In this embodiment, the filtering unit **524** is coupled between the rectifying circuit **510** and the pin **501**. The filtering circuit **520** may further include another filtering unit **525** coupled between one of the pins **501** and **502** and one of the diodes of the rectifying circuit **510**, or between one of the pins **503** and **504** and one of the diodes of the rectifying circuit **540** to reduce or filter out electromagnetic interference (EMI). In this embodiment, the filtering unit **525** is coupled between the pin **501** and one of diodes (not shown in FIG. **10**A) of the rectifying circuit **510**. Since the filtering units **524** and **525** may be present or omitted depending on actual circumstances of their uses, they are depicted by a dotted line in FIG. **10**A.

FIG. **10**B is a schematic diagram of the filtering unit according to an embodiment. Referring to FIG. **10**B, a filtering unit **623** includes a capacitor **625** having an end coupled to the output terminal **511** and a filtering output terminal **521** and the other end thereof coupled to the output terminal **512** and a filtering output terminal **522**, and is configured to low-pass filter a rectified signal from the output terminals **511** and **512**, so as to filter out high-frequency components of the rectified signal and thereby output a filtered signal at the filtering output terminals **521** and **522**.

FIG. **10**C is a schematic diagram of the filtering unit according to an embodiment. Referring to FIG. **10**C, a filtering unit **723** includes a pi filter circuit including a capacitor **725**, an inductor **726**, and a capacitor **727**. As is well known, a pi filter circuit looks like the symbol π in its shape or structure. The capacitor **725** has an end connected to the output terminal **511** and coupled to the filtering output terminal **521** through the inductor **726**, and has another end connected to the output terminal **512** and the filtering output terminal **522**. The inductor **726** is coupled between output terminal **511** and the filtering output terminal **521**. The capacitor **727** has an end connected to the filtering output terminal **521** and coupled to the output terminal **511** through the inductor **726**, and has another end connected to the output terminal **512** and the filtering output terminal **522**.

As seen between the output terminals **511** and **512** and the filtering output terminals **521** and **522**, the filtering unit **723** compared to the filtering unit **623** in FIG. **10**B additionally has an inductor **726** and a capacitor **727**, which perform the function of low-pass filtering like the capacitor **725** does. Therefore, the filtering unit **723** in this embodiment compared to the filtering unit **623** in FIG. **10**B has a better ability to filter out high-frequency components to output a filtered signal with a smoother waveform.

The inductance values of the inductor **726** in the embodiments mentioned above are chosen in the range of, for example in some embodiments, about 10 nH to 10 mH. And the capacitance values of the capacitors **625**, **725**, and **727** in the embodiments stated above are chosen in the range of, for example in some embodiments, about 100 pF to 1 uF.

FIG. **11**A is a schematic diagram of an LED module according to an embodiment. Referring to FIG. **11**A, an LED module **630** has an anode connected to a filtering output terminal **521**, a cathode connected to a filtering output terminal **522**, and includes at least one LED unit **632**, such as the light source mentioned above. When two or more LED units are included, they are connected in parallel. The anode of each LED unit **632** is connected to the anode of

LED module **630** to couple with the filtering output terminal **521**, and the cathode of each LED unit **632** is connected to the cathode of LED module **630** to couple to the filtering output terminal **522**. Each LED unit **632** includes at least one LED **631**. When multiple LEDs **631** are included in an LED unit **632**, they are connected in series with the anode of the first LED **631** connected to the anode of this LED unit **632** and the cathode of the first LED **631** connected to the next or second LED **631**. And the anode of the last LED **631** in this LED unit **632** is connected to the cathode of a previous LED **631** and the cathode of the last LED **631** connected to the cathode of this LED unit **632**.

In some embodiments, the LED module **630** may produce a current detection signal S**531** reflecting the magnitude of current through the LED module **630** and being used for controlling or detecting the LED module **630**.

FIG. **11**B is a schematic diagram of an LED module according to an exemplary embodiment. Referring to FIG. **11**B, an LED module **630** has an anode connected to a filtering output terminal **521**, a cathode connected to a filtering output terminal **522**, and includes at least two LED units **732** with the anode of each LED unit **732** connected to the anode of LED module **630** and the cathode of each LED unit **732** connected to the cathode of LED module **630**. Each LED unit **732** includes at least two LEDs **731** connected in the same way as those described in FIG. **11**A. For example, the anode of the first LED **731** in an LED unit **732** is connected to the anode of this LED unit **732**, the cathode of the first LED **731** is connected to the anode of the next or second LED **731**, and the cathode of the last LED **731** is connected to the cathode of this LED unit **732**. Further, LED units **732** in an LED module **630** are connected to each other in this embodiment. All of the n-th LEDs **731** in the related LED units **732** thereof are connected by their anodes and cathodes, such as those shown in FIG. **11**B but not limit to, where n is a positive integer. In this way, the LEDs in the LED module **630** of this embodiment are connected in the form of a mesh.

In some embodiments, the LED lighting module **530** in the above embodiments includes the LED module **630**, but doesn't include a driving circuit for the LED module **630**.

Also, the LED module **630** in this embodiment may produce a current detection signal S**531** reflecting the magnitude of current through the LED module **630** and being used for controlling or detecting the LED module **630**.

In some embodiments, the number of LEDs **731** included by an LED unit **732** is in the range of 15-25, and may be in some embodiments in the range of 18-22.

FIG. **11**C is a plan view of a circuit layout of the LED module according to an embodiment. Referring to FIG. **11**C, in this embodiment, multiple LEDs **831** are connected in the same way as described in FIG. **11**B, and three LED units are assumed in the LED module **630** and described as follows for illustration. A positive conductive line **834** and a negative conductive line **835** are to receive a driving signal for supplying power to the LEDs **831**. For example, the positive conductive line **834** may be coupled to the filtering output terminal **521** of the filtering circuit **520** described above, and the negative conductive line **835** coupled to the filtering output terminal **522** of the filtering circuit **520** to receive a filtered signal. For the convenience of illustration, all three of the n-th LEDs **831** in the three related LED units thereof are grouped as an LED set **833** in FIG. **11**C.

The positive conductive line **834** connects the three first LEDs **831** of the leftmost three related LED units thereof, that is, connects the anodes on the left sides of the three first LEDs **831** as shown in the leftmost LED set **833** of FIG.

11C. The negative conductive line **835** connects the three last LEDs **831** of the rightmost three corresponding LED units thereof, that is, connects the cathodes on the right sides of the three last LEDs **831** as shown in the rightmost LED set **833** of FIG. **11**C. The cathodes of the three first LEDs **831**, the anodes of the three last LEDs **831**, and the anodes and cathodes of all the remaining LEDs **831** are connected by conductive lines or parts **839**.

For example, the anodes of the three LEDs **831** in the leftmost LED set **833** may be connected together by the positive conductive line **834**, and their cathodes may be connected together by a leftmost conductive part **839**. The anodes of the three LEDs **831** in the second, next-leftmost LED set **833** are also connected together by the leftmost conductive part **839**, whereas their cathodes are connected together by a second, next-leftmost conductive part **839**. Since the cathodes of the three LEDs **831** in the leftmost LED set **833** and the anodes of the three LEDs **831** in the second, next-leftmost LED set **833** are connected together by the same leftmost conductive part **839**, the cathode of the first LED **831** in each of the three LED units is connected to the anode of the next or second LED **831**. As for the remaining LEDs **831** are also connected in the same way. Accordingly, all the LEDs **831** of the three LED units are connected to form the mesh as shown in FIG. **11**B.

In this embodiment, the length **836** of a portion of each conductive part **839** that connects to the anode of an LED **831** is smaller than the length **837** of another portion of each conductive part **839** that connects to the cathode of an LED **831**. This makes the area of the latter portion connecting to the cathode larger than that of the former portion connecting to the anode. Moreover, the length **837** may be smaller than a length **838** of a portion of each conductive part **839** that connects the cathode of an LED **831** and the anode of the next LED **831** in two adjacent LED sets **833**. This makes the area of the portion of each conductive part **839** that connects a cathode and an anode larger than the area of any other portion of each conductive part **839** that connects to only a cathode or an anode of an LED **831**. Due to the length differences and area differences, this layout structure improves heat dissipation of the LEDs **831**.

In some embodiments, the positive conductive line **834** includes a lengthwise portion **834***a*, and the negative conductive line **835** includes a lengthwise portion **835***a*, which are conducive to make the LED module have a positive "+" connective portion and a negative "–" connective portion at each of the two ends of the LED module, as shown in FIG. **11**C. Such a layout structure allows for coupling any of other circuits of the power supply module of the LED lamp, including e.g. the filtering circuit **520** and the rectifying circuits **510** and **540**, to the LED module through the positive connective portion and/or the negative connective portion at each or both ends of the LED lamp. Thus the layout structure increases the flexibility in arranging actual circuits in the LED lamp.

FIG. **11**D is a plan view of a circuit layout of the LED module according to another embodiment. Referring to FIG. **11**D, in this embodiment, multiple LEDs **931** are connected in the same way as described in FIG. **11**A, and three LED units each including 7 LEDs **931** are assumed in the LED module **630** and described as follows for illustration. A positive conductive line **934** and a negative conductive line **935** are to receive a driving signal for supplying power to the LEDs **931**. For example, the positive conductive line **934** may be coupled to the filtering output terminal **521** of the filtering circuit **520** described above, and the negative conductive line **935** is coupled to the filtering output terminal **522** of the filtering circuit **520**, so as to receive a filtered signal. For the convenience of illustration, all seven LEDs **931** of each of the three LED units are grouped as an LED set **932** in FIG. **11**D. Thus there are three LED sets **932** corresponding to the three LED units.

The positive conductive line **934** connects the anode on the left side of the first or leftmost LED **931** of each of the three LED sets **932**. The negative conductive line **935** connects the cathode on the right side of the last or rightmost LED **931** of each of the three LED sets **932**. In each LED set **932** of each two adjacent LEDs **931**, the LED **931** on the left has a cathode connected by a conductive part **939** to an anode of the LED **931** on the right. By such a layout, the LEDs **931** of each LED set **932** are connected in series.

In some embodiments, the conductive part **939** may be used to connect an anode and a cathode of two consecutive LEDs **931** respectively. The negative conductive line **935** connects the cathode of the last or rightmost LED **931** of each of the three LED sets **932**. And the positive conductive line **934** connects the anode of the first or leftmost LED **931** of each of the three LED sets **932**. Therefore, as shown in FIG. **11**D, the length of the conductive part **939** is larger than that of the portion of negative conductive line **935** connecting to a cathode, which length is then larger than that of the portion of positive conductive line **934** connecting to an anode. For example, the length **938** of the conductive part **939** may be larger than the length **937** of the portion of negative conductive line **935** connecting a cathode of an LED **931**, which length **937** is then larger than the length **936** of the portion of the positive conductive line **934** connecting an anode of an LED **931**. Such a layout structure improves heat dissipation of the LEDs **931** in LED module **630**.

The positive conductive line **934** may include a lengthwise portion **934***a*, and the negative conductive line **935** may include a lengthwise portion **935***a*, which are conducive to make the LED module have a positive "+" connective portion and a negative "–" connective portion at each of the two ends of the LED module, as shown in FIG. **11**D. Such a layout structure allows for coupling any of other circuits of the power supply module of the LED lamp, including e.g. the filtering circuit **520** and the rectifying circuits **510** and **540**, to the LED module through the positive connective portion **934***a* and/or the negative connective portion **935***a* at each or both ends of the LED lamp. Thus the layout structure increases the flexibility in arranging actual circuits in the LED lamp.

Further, the circuit layouts as shown in FIGS. **11**C and **11**D may be implemented with a bendable circuit sheet or substrate, which may even be called flexible circuit board depending on its specific definition used. For example, the bendable circuit sheet may comprise one conductive layer where the positive conductive line **834**, the positive lengthwise portion **834***a*, the negative conductive line **835**, the negative lengthwise portion **835***a*, and the conductive parts **839** shown in FIG. **11**C, and the positive conductive line **934**, the positive lengthwise portion **934***a*, the negative conductive line **935**, the negative lengthwise portion **935***a*, and the conductive parts **939** shown in FIG. **11**D are formed by the method of etching.

FIG. **11**E is a plan view of a circuit layout of the LED module according to another embodiment. The layout structures of the LED module in FIGS. **11**E and **11**C correspond to the same way of connecting the LEDs **831** as those shown in FIG. **11**B, but the layout structure in FIG. **11**E comprises two conductive layers instead of only one conductive layer for forming the circuit layout as shown in FIG. **11**C. Referring to FIG. **11**E, the main difference from the layout in FIG.

11C is that the positive conductive line **834** and the negative conductive line **835** have a lengthwise portion **834***a* and a lengthwise portion **835***a*, respectively, that are formed in a second conductive layer instead. The difference is elaborated as follows.

In certain embodiments, referring to FIG. **7** again at the same time, a bendable circuit sheet of the LED module includes a first conductive layer **2***a* and a second conductive layer **2***c* electrically insulated from each other by a dielectric layer **2***b*. Of the two conductive layers, the positive conductive line **834**, the negative conductive line **835**, and the conductive parts **839** in FIG. **11**E are formed in first conductive layer **2***a* by the method of etching for electrically connecting the plurality of LED components **831** e.g. in a form of a mesh, whereas the positive lengthwise portion **834***a* and the negative lengthwise portion **835***a* are formed in second conductive layer **2***c* by etching for electrically connecting (the filtering output terminal of) the filtering circuit. Further, the positive conductive line **834** and the negative conductive line **835** in the first conductive layer **2***a* have via points **834***b* and via points **835***b*, respectively, for connecting to second conductive layer **2***c*. And the positive lengthwise portion **834***a* and the negative lengthwise portion **835***a* in second conductive layer **2***c* have via points **834***c* and via points **835***c*, respectively. The via points **834***b* are positioned corresponding to the via points **834***c*, for connecting the positive conductive line **834** and the positive lengthwise portion **834***a*. The via points **835***b* are positioned corresponding to the via points **835***c*, for connecting the negative conductive line **835** and the negative lengthwise portion **835***a*. An exemplary desirable way of connecting the two conductive layers **2***a* and **2***c* is to form a hole connecting each via point **834***b* and a corresponding via point **834***c*, and to form a hole connecting each via point **835***b* and a corresponding via point **835***c*, with the holes extending through the two conductive layers **2***a* and **2***c* and the dielectric layer **2***b* in-between. And the positive conductive line **834** and the positive lengthwise portion **834***a* can be electrically connected by welding metallic part(s) through the connecting hole(s), and the negative conductive line **835** and the negative lengthwise portion **835***a* can be electrically connected by welding metallic part(s) through the connecting hole(s).

Similarly, the layout structure of the LED module in FIG. **11**D may alternatively have the positive lengthwise portion **934***a* and the negative lengthwise portion **935***a* disposed in a second conductive layer to constitute a two-layered layout structure.

The positive conductive lines (**834** or **934**) may be characterized as including two end terminals at opposite ends, a plurality of pads between the two end terminals and for contacting and/or supplying power to LEDs (e.g., anodes of LEDs), and a wire portion, which may be an elongated conductive line extending along a length of an LED light strip and electrically connecting the two end terminals to the plurality of pads. Similarly, the negative conductive lines (**835** or **935**) may be characterized as including two end terminals at opposite ends, a plurality of pads between the two end terminals and for contacting and/or supplying power to LEDs (e.g., cathodes of LEDs), and a wire portion, which may be an elongated conductive line extending along a length of an LED light strip and electrically connecting the two end terminals to the plurality of pads.

The circuit layouts may be implemented for one of the exemplary LED light strips described previously, for example, to serve as a circuit board or sheet for the LED light strip on which the LED light sources are disposed.

As described herein, an LED unit may refer to a single string of LEDs arranged in series, and an LED module may refer to a single LED unit, or a plurality of LED units connected to a same two nodes (e.g., arranged in parallel). For example, the LED light strip **2** described above may be an LED module and/or LED unit.

In some embodiments, the thickness of the second conductive layer of a two-layered bendable circuit sheet is, in some embodiments, larger than that of the first conductive layer in order to reduce the voltage drop or loss along each of the positive lengthwise portion and the negative lengthwise portion disposed in the second conductive layer. Compared to a one-layered bendable circuit sheet, since a positive lengthwise portion and a negative lengthwise portion are disposed in a second conductive layer in a two-layer bendable circuit sheet, the width (between two lengthwise sides) of the two-layered bendable circuit sheet is or can be reduced. On the same fixture or plate in a production process, the number of bendable circuit sheets each with a shorter width that can be laid together at most is larger than the number of bendable circuit sheets each with a longer width that can be laid together at most. Thus adopting a bendable circuit sheet with a shorter width can increase the efficiency of production of the LED module. And reliability in the production process, such as the accuracy of welding position when welding (materials on) the LED components, can also be improved, because a two-layer bendable circuit sheet can better maintain its shape.

As a variant of the above embodiments, a type of an exemplary LED tube lamp is provided that may have at least some of the electronic components of its power supply module disposed on a light strip of the LED tube lamp. For example, the technique of printed electronic circuit (PEC) can be used to print, insert, or embed at least some of the electronic components onto the LED light strip (e.g., as opposed to being on a separate circuit board connected to the LED light strip).

In one embodiment, all electronic components of the power supply module are disposed on the light strip. The production process may include or proceed with the following steps: preparation of the circuit substrate (e.g. preparation of a flexible printed circuit board); ink jet printing of metallic nano-ink; ink jet printing of active and passive components (as of the power supply module); drying/sintering; ink jet printing of interlayer bumps; spraying of insulating ink; ink jet printing of metallic nano-ink; ink jet printing of active and passive components (to sequentially form the included layers); spraying of surface bond pad(s); and spraying of solder resist against LED components. The production process may be different, however, and still result in some or all electronic components of the power supply module being disposed directly on the LED light strip.

In certain embodiments, if all electronic components of the power supply module are disposed on the LED light strip, electrical connection between the terminal pins of the LED tube lamp and the light strip may be achieved by connecting the pins to conductive lines which are welded with ends of the light strip. In this case, another substrate for supporting the power supply module is not required, thereby allowing of an improved design or arrangement in the end cap(s) of the LED tube lamp. In some embodiments, (components of) the power supply module are disposed at two ends of the light strip, in order to significantly reduce the impact of heat generated from the power supply module's operations on the LED components. Since no substrate other than the light strip is used to support the power supply module in this case, the total amount of welding or soldering can be significantly reduced, improving the general reliability of the power supply module.

Another case is that some of all electronic components of the power supply module, such as some resistors and/or smaller size capacitors, are printed onto the light strip, and some bigger size components, such as some inductors and/or electrolytic capacitors, are disposed in the end cap(s). The production process of the light strip in this case may be the same as that described above. And in this case disposing some of all electronic components on the light strip is conducive to achieving a reasonable layout of the power supply module in the LED tube lamp, which may allow of an improved design in the end cap(s).

As a variant embodiment of the above, electronic components of the power supply module may be disposed on the LED light strip by a method of embedding or inserting, e.g. by embedding the components onto a bendable or flexible light strip. In some embodiments, this embedding may be realized by a method using copper-clad laminates (CCL) for forming a resistor or capacitor; a method using ink related to silkscreen printing; or a method of ink jet printing to embed passive components, wherein an ink jet printer is used to directly print inks to constitute passive components and related functionalities to intended positions on the light strip. Then through treatment by ultraviolet (UV) light or drying/sintering, the light strip is formed where passive components are embedded. The electronic components embedded onto the light strip include for example resistors, capacitors, and inductors. In other embodiments, active components also may be embedded. Through embedding some components onto the light strip, a reasonable layout of the power supply module can be achieved to allow of an improved design in the end cap(s), because the surface area on a printed circuit board used for carrying components of the power supply module is reduced or smaller, and as a result the size, weight, and thickness of the resulting printed circuit board for carrying components of the power supply module is also smaller or reduced. Also in this situation since welding points on the printed circuit board for welding resistors and/or capacitors if they were not to be disposed on the light strip are no longer used, the reliability of the power supply module is improved, in view of the fact that these welding points are most liable to (cause or incur) faults, malfunctions, or failures. Further, the length of conductive lines needed for connecting components on the printed circuit board is therefore also reduced, which allows of a more compact layout of components on the printed circuit board and thus improving the functionalities of these components.

As mentioned above, electronic components of the power supply module **5** or **250** may be disposed either on the light strip **2** or on a circuit board (such as a printed circuit board) in the end cap(s) of one or two ends of the lamp tube. For improving benefits or advantages of embodiments of the power supply module or the general LED tube lamp, in some embodiments, capacitor(s) in the power supply module may be chip capacitor(s), such as multilayer ceramic chip capacitor(s), disposed either on the light strip **2** or on the short circuit board **253**. However, such disposed chip capacitor(s) in use is likely to produce or incur distinct noises due to piezoelectric effects, which may adversely affect the comfort level of using the LED tube lamp by consumers. To address and reduce this problem, in the LED tube lamp of this disclosure, a hole or groove may be disposed (directly) below the chip capacitor by drilling or boring, to significantly reduce the noise by changing the vibration system formed under piezoelectric effects between the chip capacitor and the circuit board carrying the chip capacitor. The shape of the circumference of the hole or groove may be substantially close to, for example, a circle or round, an oval or ellipse, or a rectangle. In some embodiments, the hole or groove is formed in a conductive or wire layer in the light strip **2**, or in the short circuit board **253** in the end cap(s), and (directly) below the chip capacitor.

Next, methods to produce embedded capacitors and resistors are explained as follows.

Usually, methods for manufacturing embedded capacitors employ or involve a concept called distributed or planar capacitance. The manufacturing process may include the following step(s). On a substrate of a copper layer a very thin insulation layer is applied or pressed, which is then generally disposed between a pair of layers including a power conductive layer and a ground layer. The very thin insulation layer makes the distance between the power conductive layer and the ground layer very short. A capacitance resulting from this structure can also be realized by a conventional technique of a plated-through hole. Basically, this step is used to create this structure comprising a big parallel-plate capacitor on a circuit substrate.

Of products of high electrical capacity, certain types of products employ distributed capacitances, and other types of products employ separate embedded capacitances. Through putting or adding a high dielectric-constant material, such as barium titanate, into the insulation layer, the high electrical capacity is achieved.

A usual method for manufacturing embedded resistors employ conductive or resistive adhesive. This may include, for example, a resin to which conductive carbon or graphite is added, which may be used as an additive or filler. The additive resin is silkscreen printed to an object location, and is then after treatment laminated inside the circuit board. The resulting resistor is connected to other electronic components through plated-through holes or microvias. Another method is called Ohmega-Ply, by which a two metallic layer structure of a copper layer and a thin nickel alloy layer constitutes a layer resistor relative to a substrate. Then through etching the copper layer and nickel alloy layer, different types of nickel alloy resistors with copper terminals can be formed. These types of resistor are each laminated inside the circuit board.

In an embodiment, conductive wires/lines are directly printed in a linear layout on an inner surface of the LED glass lamp tube, with LED components directly attached on the inner surface and electrically connected by the conductive wires. In some embodiments, the LED components in the form of chips are directly attached over the conductive wires on the inner surface, and connective points are at terminals of the wires for connecting the LED components and the power supply module. After being attached, the LED chips may have fluorescent powder applied or dropped thereon, for producing white light or light of other color by the operating LED tube lamp.

In some embodiments, luminous efficacy of the LED or LED component is 80 lm/W or above, and in some embodiments, it may be 120 lm/W or above. Certain more optimal embodiments may include a luminous efficacy of the LED or LED component of 160 lm/W or above. White light emitted by an LED component in the invention may be produced by mixing fluorescent powder with the monochromatic light emitted by a monochromatic LED chip. The white light in its spectrum has major wavelength ranges of 430-460 nm and 550-560 nm, or major wavelength ranges of 430-460 nm, 540-560 nm, and 620-640 nm.

FIG. **12**A is a block diagram of a power supply module in an LED lamp according to an embodiment. As shown in FIG. **12**A, the power supply module of the LED lamp includes a rectifying circuit **510**, a filtering circuit **520**, and may further include some parts of an LED lighting module **530**. The LED lighting module **530** in this embodiment comprises a driving circuit **1530** and an LED module **630**. The driving circuit **1530** comprises a DC-to-DC converter circuit, and is coupled to the filtering output terminals **521** and **522** to receive a filtered signal and then perform power conversion for converting the filtered signal into a driving signal at the driving output terminals **1521** and **1522**. The LED module **630** is coupled to the driving output terminals **1521** and **1522** to receive the driving signal for emitting light. In some embodiments, the current of LED module **630** is stabilized at an objective current value. Descriptions of this LED module **630** are the same as those provided above with reference to FIGS. **11**A-**11**E.

In some embodiments, the LED lighting module **530** shown in FIG. **8**C may include the driving circuit **1530** and the LED module **630** as shown in FIG. **12**A. Thus, the power supply module for the LED lamp in the present embodiment can be applied to the single-end power supply structure, such as LED light bulbs, personal area lights (PAL), and so forth.

FIG. **12**B is a block diagram of the driving circuit according to an embodiment. Referring to FIG. **12**B, a driving circuit includes a controller **1531**, and a conversion circuit **1532** for power conversion based on a current source, for driving the LED module to emit light. The conversion circuit **1532** includes a switching circuit **1535** and an energy storage circuit **1538**. And the conversion circuit **1532** is coupled to the filtering output terminals **521** and **522** to receive and then convert a filtered signal, under the control by the controller **1531**, into a driving signal at the driving output terminals **1521** and **1522** for driving the LED module. Under the control by the controller **1531**, the driving signal output by the conversion circuit **1532** comprises a steady current, making the LED module emitting steady light.

FIG. **12**C is a schematic diagram of the driving circuit according to an embodiment. Referring to FIG. **12**C, a driving circuit **1630** in this embodiment comprises a buck DC-to-DC converter circuit having a controller **1631** and a converter circuit. The converter circuit includes an inductor **1632**, a diode **1633** for "freewheeling" of current, a capacitor **1634**, and a switch **1635**. The driving circuit **1630** is coupled to the filtering output terminals **521** and **522** to receive and then convert a filtered signal into a driving signal for driving an LED module connected between the driving output terminals **1521** and **1522**.

In this embodiment, the switch **1635** includes a metal-oxide-semiconductor field-effect transistor (MOSFET) and has a first terminal coupled to the anode of freewheeling diode **1633**, a second terminal coupled to the filtering output terminal **522**, and a control terminal coupled to the controller **1631** used for controlling current conduction or cutoff between the first and second terminals of switch **1635**. The driving output terminal **1521** is connected to the filtering output terminal **521**, and the driving output terminal **1522** is connected to an end of the inductor **1632**, which has another end connected to the first terminal of switch **1635**. The capacitor **1634** is coupled between the driving output terminals **1521** and **1522** to stabilize the voltage between the driving output terminals **1521** and **1522**. The freewheeling diode **1633** has a cathode connected to the driving output terminal **1521**.

Next, a description follows as to an exemplary operation of the driving circuit **1630**.

The controller **1631** is configured for determining when to turn the switch **1635** on (in a conducting state) or off (in a cutoff state) according to a current detection signal S**535** and/or a current detection signal S**531**. For example, in some embodiments, the controller **1631** is configured to control the duty cycle of switch **1635** being on and switch **1635** being off in order to adjust the size or magnitude of the driving signal. The current detection signal S**535** represents the magnitude of current through the switch **1635**. The current detection signal S**531** represents the magnitude of current through the LED module coupled between the driving output terminals **1521** and **1522**. The controller **1631** may control the duty cycle of the switch **1635** being on and off, based on, for example, a magnitude of a current detected based on current detection signal S**531** or S**535**. As such, when the magnitude is above a threshold, the switch may be off (cutoff state) for more time, and when magnitude goes below the threshold, the switch may be on (conducting state) for more time. According to any of current detection signal S**535** and current detection signal S**531**, the controller **1631** can obtain information on the magnitude of power converted by the converter circuit. When the switch **1635** is switched on, a current of a filtered signal is input through the filtering output terminal **521**, and then flows through the capacitor **1634**, the driving output terminal **1521**, the LED module, the inductor **1632**, and the switch **1635**, and then flows out from the filtering output terminal **522**. During this flowing of current, the capacitor **1634** and the inductor **1632** are performing storing of energy. On the other hand, when the switch **1635** is switched off, the capacitor **1634** and the inductor **1632** perform releasing of stored energy by a current flowing from the freewheeling diode **1633** to the driving output terminal **1521** to make the LED module continuing to emit light.

In some embodiments, the capacitor **1634** is an optional element, so it can be omitted and is thus depicted in a dotted line in FIG. **12**C. In some application environments, the natural characteristic of an inductor to oppose instantaneous change in electric current passing through the inductor may be used to achieve the effect of stabilizing the current through the LED module, thus omitting the capacitor **1634**.

As described above, because the driving circuit **1630** is configured for determining when to turn a switch **1635** on (in a conducting state) or off (in a cutoff state) according to a current detection signal S**535** and/or a current detection signal S**531**, the driving circuit **1630** can maintain a stable current flow through the LED module. Therefore, the color temperature may not change with current to some LED module, such as white, red, blue, green LED modules. For example, an LED can retain the same color temperature under different illumination conditions. In some embodiments, because the inductor **1632** playing the role of the energy-storing circuit releases the stored power when the switch **1635** cuts off, the voltage/current flowing through the LED module remains above a predetermined voltage/current level so that the LED module may continue to emit light maintaining the same color temperature. In this way, when the switch **1635** conducts again, the voltage/current flowing through the LED module does not need to be adjusted to go from a minimum value to a maximum value. Accordingly, the LED module lighting with flickering can be avoided, the entire illumination can be improved, the lowest conducting period can be smaller, and the driving frequency can be higher.

FIG. **12**D is a schematic diagram of the driving circuit according to an embodiment. Referring to FIG. **12**D, a driving circuit **1730** in this embodiment comprises a boost

DC-to-DC converter circuit having a controller **1731** and a converter circuit. The converter circuit includes an inductor **1732**, a diode **1733** for "freewheeling" of current, a capacitor **1734**, and a switch **1735**. The driving circuit **1730** is configured to receive and then convert a filtered signal from the filtering output terminals **521** and **522** into a driving signal for driving an LED module coupled between the driving output terminals **1521** and **1522**.

The inductor **1732** has an end connected to the filtering output terminal **521**, and another end connected to the anode of freewheeling diode **1733** and a first terminal of the switch **1735**, which has a second terminal connected to the filtering output terminal **522** and the driving output terminal **1522**. The freewheeling diode **1733** has a cathode connected to the driving output terminal **1521**. And the capacitor **1734** is coupled between the driving output terminals **1521** and **1522**.

The controller **1731** is coupled to a control terminal of switch **1735**, and is configured for determining when to turn the switch **1735** on (in a conducting state) or off (in a cutoff state), according to a current detection signal S**535** and/or a current detection signal S**531**. When the switch **1735** is switched on, a current of a filtered signal is input through the filtering output terminal **521**, and then flows through the inductor **1732** and the switch **1735**, and then flows out from the filtering output terminal **522**. During this flowing of current, the current through the inductor **1732** increases with time, with the inductor **1732** being in a state of storing energy, while the capacitor **1734** enters a state of releasing energy, making the LED module continuing to emit light. On the other hand, when the switch **1735** is switched off, the inductor **1732** enters a state of releasing energy as the current through the inductor **1732** decreases with time. In this state, the current through the inductor **1732** then flows through the freewheeling diode **1733**, the capacitor **1734**, and the LED module, while the capacitor **1734** enters a state of storing energy.

In some embodiments the capacitor **1734** is an optional element, so it can be omitted and is thus depicted in a dotted line in FIG. **12**D. When the capacitor **1734** is omitted and the switch **1735** is switched on, the current of inductor **1732** does not flow through the LED module, making the LED module not emit light; but when the switch **1735** is switched off, the current of inductor **1732** flows through the freewheeling diode **1733** to reach the LED module, making the LED module emit light. Therefore, by controlling the time that the LED module emits light, and the magnitude of current through the LED module, the average luminance of the LED module can be stabilized to be above a defined value, thus also achieving the effect of emitting a steady light.

As described above, because the controller **1731** included in the driving circuit **1730** is coupled to the control terminal of switch **1735**, and is configured for determining when to turn a switch **1735** on (in a conducting state) or off (in a cutoff state), according to a current detection signal S**535** and/or a current detection signal S**531**, the driving circuit **1730** can maintain a stable current flow through the LED module. Therefore, the color temperature may not change with current to some LED modules, such as white, red, blue, or green LED modules. For example, an LED can retain the same color temperature under different illumination conditions. In some embodiments, because the inductor **1732** playing the role of the energy-storing circuit releases the stored power when the switch **1735** cuts off, the voltage/current flowing through the LED module remains above a predetermined voltage/current level so that the LED module may continue to emit light maintaining the same color temperature. In this way, when the switch **1735** conducts again, the voltage/current flowing through the LED module does not need to be adjusted to go from a minimum value to a maximum value. Accordingly, the LED module lighting with flickering can be avoided, the entire illumination can be improved, the lowest conducting period can be smaller, and the driving frequency can be higher.

FIG. **12**E is a schematic diagram of the driving circuit according to an exemplary embodiment. Referring to FIG. **12**E, a driving circuit **1830** in this embodiment comprises a buck DC-to-DC converter circuit having a controller **1831** and a converter circuit. The converter circuit includes an inductor **1832**, a diode **1833** for "freewheeling" of current, a capacitor **1834**, and a switch **1835**. The driving circuit **1830** is coupled to the filtering output terminals **521** and **522** to receive and then convert a filtered signal into a driving signal for driving an LED module connected between the driving output terminals **1521** and **1522**.

The switch **1835** has a first terminal coupled to the filtering output terminal **521**, a second terminal coupled to the cathode of freewheeling diode **1833**, and a control terminal coupled to the controller **1831** to receive a control signal from the controller **1831** for controlling current conduction or cutoff between the first and second terminals of the switch **1835**. The anode of freewheeling diode **1833** is connected to the filtering output terminal **522** and the driving output terminal **1522**. The inductor **1832** has an end connected to the second terminal of switch **1835**, and another end connected to the driving output terminal **1521**. The capacitor **1834** is coupled between the driving output terminals **1521** and **1522** to stabilize the voltage between the driving output terminals **1521** and **1522**.

The controller **1831** is configured for controlling when to turn the switch **1835** on (in a conducting state) or off (in a cutoff state) according to a current detection signal S**535** and/or a current detection signal S**531**. When the switch **1835** is switched on, a current of a filtered signal is input through the filtering output terminal **521**, and then flows through the switch **1835**, the inductor **1832**, and the driving output terminals **1521** and **1522**, and then flows out from the filtering output terminal **522**. During this flowing of current, the current through the inductor **1832** and the voltage of the capacitor **1834** both increase with time, so the inductor **1832** and the capacitor **1834** are in a state of storing energy. On the other hand, when the switch **1835** is switched off, the inductor **1832** is in a state of releasing energy and thus the current through it decreases with time. In this case, the current through the inductor **1832** circulates through the driving output terminals **1521** and **1522**, the freewheeling diode **1833**, and back to the inductor **1832**.

In some embodiments the capacitor **1834** is an optional element, so it can be omitted and is thus depicted in a dotted line in FIG. **12**E. When the capacitor **1834** is omitted, no matter whether the switch **1835** is turned on or off, the current through the inductor **1832** will flow through the driving output terminals **1521** and **1522** to drive the LED module to continue emitting light.

As described above, because the controller **1831** included in the driving circuit **1830** is configured for controlling when to turn a switch **1835** on (in a conducting state) or off (in a cutoff state) according to a current detection signal S**535** and/or a current detection signal S**531**, the driving circuit **1730** can maintain a stable current flow through the LED module. Therefore, the color temperature may not change with current to some LED modules, such as white, red, blue, or green LED modules. For example, an LED can retain the same color temperature under different illumination conditions. In some embodiments, because the inductor **1832** playing the role of the energy-storing circuit releases the stored power when the switch **1835** cuts off, the voltage/current flowing through the LED module remains above a predetermined voltage/current level so that the LED module may continue to emit light maintaining the same color temperature. In this way, when the switch **1835** conducts again, the voltage/current flowing through the LED module does not need to be adjusted to go from a minimum value to a maximum value. Accordingly, the LED module lighting with flickering can be avoided, the entire illumination can be improved, the lowest conducting period can be smaller, and the driving frequency can be higher.

FIG. **12**F is a schematic diagram of the driving circuit according to an exemplary embodiment. Referring to FIG. **12**F, a driving circuit **1930** in this embodiment comprises a buck DC-to-DC converter circuit having a controller **1931** and a converter circuit. The converter circuit includes an inductor **1932**, a diode **1933** for "freewheeling" of current, a capacitor **1934**, and a switch **1935**. The driving circuit **1930** is coupled to the filtering output terminals **521** and **522** to receive and then convert a filtered signal into a driving signal for driving an LED module connected between the driving output terminals **1521** and **1522**.

The inductor **1932** has an end connected to the filtering output terminal **521** and the driving output terminal **1522**, and another end connected to a first end of the switch **1935**. The switch **1935** has a second end connected to the filtering output terminal **522**, and a control terminal connected to controller **1931** to receive a control signal from controller **1931** for controlling current conduction or cutoff of the switch **1935**. The freewheeling diode **1933** has an anode coupled to a node connecting the inductor **1932** and the switch **1935**, and a cathode coupled to the driving output terminal **1521**. The capacitor **1934** is coupled to the driving output terminals **1521** and **1522** to stabilize the driving of the LED module coupled between the driving output terminals **1521** and **1522**.

The controller **1931** is configured for controlling when to turn the switch **1935** on (in a conducting state) or off (in a cutoff state) according to a current detection signal S**531** and/or a current detection signal S**535**. When the switch **1935** is turned on, a current is input through the filtering output terminal **521**, and then flows through the inductor **1932** and the switch **1935**, and then flows out from the filtering output terminal **522**. During this flowing of current, the current through the inductor **1932** increases with time, so the inductor **1932** is in a state of storing energy; but the voltage of the capacitor **1934** decreases with time, so the capacitor **1934** is in a state of releasing energy to keep the LED module continuing to emit light. On the other hand, when the switch **1935** is turned off, the inductor **1932** is in a state of releasing energy and its current decreases with time. In this case, the current through the inductor **1932** circulates through the freewheeling diode **1933**, the driving output terminals **1521** and **1522**, and back to the inductor **1932**. During this circulation, the capacitor **1934** is in a state of storing energy and its voltage increases with time.

In some embodiments the capacitor **1934** is an optional element, so it can be omitted and is thus depicted in a dotted line in FIG. **12**F. When the capacitor **1934** is omitted and the switch **1935** is turned on, the current through the inductor **1932** doesn't flow through the driving output terminals **1521** and **1522**, thereby making the LED module not emit light. On the other hand, when the switch **1935** is turned off, the current through the inductor **1932** flows through the freewheeling diode **1933** and then the LED module to make the LED module emit light. Therefore, by controlling the time that the LED module emits light, and the magnitude of current through the LED module, the average luminance of the LED module can be stabilized to be above a defined value, thus also achieving the effect of emitting a steady light.

As described above, because the controller **1931** included in the driving circuit **1930** is configured for controlling when to turn a switch **1935** on (in a conducting state) or off (in a cutoff state) according to a current detection signal S**535** and/or a current detection signal S**531**, the driving circuit **1930** can maintain a stable current flow through the LED module. Therefore, the color temperature may not change with current to some LED modules, such as white, red, blue, or green LED modules. For example, an LED can retain the same color temperature under different illumination conditions. In some embodiments, because the inductor **1932** playing the role of the energy-storing circuit releases the stored power when the switch **1935** cuts off, the voltage/current flowing through the LED module remains above a predetermined voltage/current level so that the LED module may continue to emit light maintaining the same color temperature. In this way, when the switch **1935** conducts again, the voltage/current flowing through the LED module does not need to be adjusted to go from a minimum value to a maximum value. Accordingly, the LED module lighting with flickering can be avoided, the entire illumination can be improved, the lowest conducting period can be smaller, and the driving frequency can be higher.

With reference to FIGS. **5** and **6**, a short circuit board **253** includes a first short circuit substrate and a second short circuit substrate respectively connected to two terminal portions of a long circuit sheet **251**, and electronic components of the power supply module are respectively disposed on the first short circuit substrate and the second short circuit substrate. The first short circuit substrate and the second short circuit substrate may have roughly the same length, or different lengths. In general, the first short circuit substrate (i.e. the right circuit substrate of short circuit board **253** in FIG. **5** and the left circuit substrate of short circuit board **253** in FIG. **6**) has a length that is about 30%-80% of the length of the second short circuit substrate (i.e. the left circuit substrate of short circuit board **253** in FIG. **5** and the right circuit substrate of short circuit board **253** in FIG. **6**). In some embodiments the length of the first short circuit substrate is about ⅓-⅔ of the length of the second short circuit substrate. For example, in one embodiment, the length of the first short circuit substrate may be about half the length of the second short circuit substrate. The length of the second short circuit substrate may be, for example in the range of about 15 mm to about 65 mm, depending on actual application occasions. In certain embodiments, the first short circuit substrate is disposed in an end cap at an end of the LED tube lamp, and the second short circuit substrate is disposed in another end cap at the opposite end of the LED tube lamp.

For example, capacitors of the driving circuit, such as the capacitors **1634**, **1734**, **1834**, and **1934** in FIGS. **12**C-**12**F, in practical use may include two or more capacitors connected in parallel. Some or all capacitors of the driving circuit in the power supply module may be arranged on the first short circuit substrate of short circuit board **253**, while other components such as the rectifying circuit, filtering circuit, inductor(s) of the driving circuit, controller(s), switch(es), diodes, etc. are arranged on the second short circuit substrate of short circuit board **253**. Since the inductors, controllers, switches, etc. are electronic components with higher temperature, arranging some or all capacitors on a circuit substrate separate or away from the circuit substrate(s) of high-temperature components helps prevent the working life of capacitors (especially electrolytic capacitors) from being negatively affected by the high-temperature components, thus improving the reliability of the capacitors. Further, the physical separation between the capacitors and both the rectifying circuit and filtering circuit also contributes to reducing the problem of EMI.

In certain exemplary embodiments, the conversion efficiency of the driving circuits is above 80%. In some embodiments, the conversion efficiency of the driving circuits is above 90%. In still other embodiments, the conversion efficiency of the driving circuits is above 92%. The illumination efficiency of the LED lamps is above 120 lm/W. In some embodiments, the illumination efficiency of the LED lamps is above 160 lm/W. The illumination efficiency including the combination of the driving circuits and the LED modules is above 120 lm/W*90%=108 lm/W. In some embodiments, the illumination efficiency including the combination of the driving circuits and the LED modules is above 160 lm/W*92%=147.21 lm/W.

In some embodiments, the transmittance of the diffusion film in the LED tube lamp is above 85%. As a result, in certain embodiments, the illumination efficiency of the LED lamps is above 108 lm/W*85%=91.8 lm/W. In some embodiments, the illumination efficiency of the LED lamps is above 147.21 lm/W*85%=125.12 lm/W.

FIG. **13**A is a block diagram of a power supply module in an LED tube lamp according to an exemplary embodiment. Compared to that shown in FIG. **8**C, the present embodiment comprises a rectifying circuit **510**, a filtering circuit **520**, and a driving circuit **1530**, and further comprises an over voltage protection (OVP) circuit **1570**. In this embodiment, a driving circuit **1530** and an LED module **630** compose the LED lighting module **530**. The OVP circuit **1570** is coupled to the filtering output terminals **521** and **522** for detecting the filtered signal. The OVP circuit **1570** clamps the logic level of the filtered signal when determining the logic level thereof higher than a defined OVP value. Hence, the OVP circuit **1570** protects the LED lighting module **530** from damage due to an OVP condition.

FIG. **13**B is a schematic diagram of an overvoltage protection (OVP) circuit according to an exemplary embodiment. An OVP circuit **1670** comprises a voltage clamping diode **1671**, such as zener diode, coupled to the filtering output terminals **521** and **522**. The voltage clamping diode **1671** is conducted to clamp a voltage difference at a breakdown voltage when the voltage difference of the filtering output terminals **521** and **522** (i.e., the logic level of the filtered signal) reaches the breakdown voltage. In some embodiments, the breakdown voltage may be in a range of about 40 V to about 100 V. In certain embodiments, the breakdown voltage may be in a range of about 55 V to about 75V.

FIG. **14**A is a block diagram of a power supply module in an LED tube lamp according to an exemplary embodiment. Compared to that shown in FIG. **8**C, the present embodiment comprises a rectifying circuit **510**, a filtering circuit **520**, and a driving circuit **1530**, and further comprises an auxiliary power module **2510**. The auxiliary power module **2510** is coupled between the filtering output terminals **521** and **522**. The auxiliary power module **2510** detects the filtered signal in the filtering output terminals **521** and **522**, and determines whether providing an auxiliary power to the filtering output terminals **521** and **522** based on the detected result. When the supply of the filtered signal is stopped or a logic level thereof is insufficient, i.e., when a drive voltage for the LED module is below a defined voltage, the auxiliary power module provides auxiliary power to keep the LED lighting module **530** continuing to emit light. The defined voltage is determined according to an auxiliary power voltage of the auxiliary power module **2510**.

FIG. **14**B is a block diagram of a power supply module in an LED tube lamp according to an exemplary embodiment. Compared to that shown in FIG. **14**A, the present embodiment comprises a rectifying circuit **510**, a filtering circuit **520**, and may further include some parts of an LED lighting module **530**, and an auxiliary power module **2510**, and the LED lighting module **530** further comprises a driving circuit **1530** and an LED module **630**. The auxiliary power module **2510** is coupled between the driving output terminals **1521** and **1522**. The auxiliary power module **2510** detects the driving signal in the driving output terminals **1521** and **1522**, and determines whether to provide an auxiliary power to the driving output terminals **1521** and **1522** based on the detected result. When the driving signal is no longer being supplied or a logic level thereof is insufficient, the auxiliary power module **2510** provides the auxiliary power to keep the LED module **630** continuously light.

FIG. **14**C is a schematic diagram of an auxiliary power module according to an embodiment. The auxiliary power module **2610** comprises an energy storage unit **2613** and a voltage detection circuit **2614**. The auxiliary power module further comprises an auxiliary power positive terminal **2611** and an auxiliary power negative terminal **2612** for being respectively coupled to the filtering output terminals **521** and **522** or the driving output terminals **1521** and **1522**. The voltage detection circuit **2614** detects a logic level of a signal at the auxiliary power positive terminal **2611** and the auxiliary power negative terminal **2612** to determine whether releasing outward the power of the energy storage unit **2613** through the auxiliary power positive terminal **2611** and the auxiliary power negative terminal **2612**.

In some embodiments, the energy storage unit **2613** is a battery or a supercapacitor. When a voltage difference of the auxiliary power positive terminal **2611** and the auxiliary power negative terminal **2612** (the drive voltage for the LED module) is higher than the auxiliary power voltage of the energy storage unit **2613**, the voltage detection circuit **2614** charges the energy storage unit **2613** by the signal in the auxiliary power positive terminal **2611** and the auxiliary power negative terminal **2612**. When the drive voltage is lower than the auxiliary power voltage, the energy storage unit **2613** releases the stored energy outward through the auxiliary power positive terminal **2611** and the auxiliary power negative terminal **2612**.

The voltage detection circuit **2614** comprises a diode **2615**, a bipolar junction transistor (BJT) **2616** and a resistor **2617**. A positive end of the diode **2615** is coupled to a positive end of the energy storage unit **2613** and a negative end of the diode **2615** is coupled to the auxiliary power positive terminal **2611**. The negative end of the energy storage unit **2613** is coupled to the auxiliary power negative terminal **2612**. A collector of the BJT **2616** is coupled to the auxiliary power positive terminal **2611**, and an emitter thereof is coupled to the positive end of the energy storage unit **2613**. One end of the resistor **2617** is coupled to the auxiliary power positive terminal **2611** and the other end is coupled to a base of the BJT **2616**. When the collector of the BJT **2616** is a cut-in voltage higher than the emitter thereof, the resistor **2617** conducts the BJT **2616**. When the power source provides power to the LED tube lamp normally, the energy storage unit **2613** is charged by the filtered signal through the filtering output terminals **521** and **522** and the conducted BJT **2616** or by the driving signal through the driving output terminals **1521** and **1522** and the conducted BJT **2616** until that the collector-emitter voltage of the BJT **2616** is lower than or equal to the cut-in voltage. When the filtered signal or the driving signal is no longer being supplied or the logic level thereof is insufficient, the energy storage unit **2613** provides power through the diode **2615** to keep the LED lighting module **530** or the LED module **630** continuously light.

In some embodiments, the maximum voltage of the charged energy storage unit **2613** is at least one cut-in voltage of the BJT **2616** lower than the voltage difference applied between the auxiliary power positive terminal **2611** and the auxiliary power negative terminal **2612**. The voltage difference provided between the auxiliary power positive terminal **2611** and the auxiliary power negative terminal **2612** is a turn-on voltage of the diode **2615** lower than the voltage of the energy storage unit **2613**. Hence, when the auxiliary power module **2610** provides power, the voltage applied at the LED module **630** is lower (about the sum of the cut-in voltage of the BJT **2616** and the turn-on voltage of the diode **2615**). In the embodiment shown in the FIG. **14**B, the brightness of the LED module **630** is reduced when the auxiliary power module supplies power thereto. Thereby, when the auxiliary power module is applied to an emergency lighting system or a constant lighting system, the user realizes the main power supply, such as commercial power, is abnormal and then performs necessary precautions therefor.

Referring to FIG. **15**A, a block diagram of an LED tube lamp including a power supply module in accordance with certain embodiments is illustrated. Compared to the LED lamp shown in FIG. **8**C, the LED tube lamp of FIG. **15**A includes a rectifying circuit **510**, a filtering circuit **520**, and an LED lighting module **530**, and further includes an installation detection module **2520**. The installation detection module **2520** is coupled to the rectifying circuit **510** via an installation detection terminal **2521** and is coupled to the filtering circuit **520** via an installation detection terminal **2522**. The installation detection module **2520** detects the signal passing through the installation detection terminals **2521** and **2522** and determines whether to cut off an LED driving signal (e.g., an external driving signal) passing through the LED tube lamp based on the detected result. The installation detection module **2520** includes circuitry configured to perform the steps of detecting the signal passing through the installation detection terminals **2521** and **2522** and determining whether to cut off an LED driving signal, and thus may be referred to as an installation detection circuit, or more generally as a detection circuit or cut-off circuit. When an LED tube lamp is not yet installed on a lamp socket or holder, or in some cases if it is not installed properly or is only partly installed (e.g., one side is connected to a lamp socket, but not the other side yet), the installation detection module **2520** detects a smaller current compared to a predetermined current (or current value) and determines the signal is passing through a high impedance through the installation detection terminals **2521** and **2522**. In this case, in certain embodiments, the installation detection circuit **2520** is in a cut-off state to make the LED tube lamp stop working. Otherwise, the installation detection module **2520** determines that the LED tube lamp has already been installed on the lamp socket or holder (e.g., when the installation detection module **2520** detects a current equal to or larger than a predetermined current and determines the signal is passing through a low impedance through the installation detection terminals **2521** and **2522**), and maintains conducting state to make the LED tube lamp working normally.

For example, in some embodiments, when a current passing through the installation detection terminals **2521** and **2522** is greater than or equal to a specific, defined installation current (or a current value), which may indicate that the current supplied to the LED lighting module **530** is greater than or equal to a specific, defined operating current, the installation detection module **2520** is conducting to make the LED tube lamp operate in a conducting state. For example, a current greater than or equal to the specific current value may indicate that the LED tube lamp has correctly been installed in the lamp socket or holder. When the current passing through the installation detection terminals **2521** and **2522** is smaller than the specific, defined installation current (or the current value), which may indicate that the current supplied to the LED lighting module **530** is less than a specific, defined operating current, the installation detection module **2520** cuts off current to make the LED tube lamp enter in a non-conducting state based on determining that the LED tube lamp has been not installed in, or does not properly connect to, the lamp socket or holder. In certain embodiments, the installation detection module **2520** determines conducting or cutting off based on the impedance detection to make the LED tube lamp operate in a conducting state or enter non-conducting state. The LED tube lamp operating in a conducting state may refer to the LED tube lamp including a sufficient current passing through the LED module to cause the LED light sources to emit light. The LED tube lamp operating in a cut-off state may refer to the LED tube lamp including an insufficient current or no current passing through the LED module so that the LED light sources do not emit light. Accordingly, the occurrence of electric shock caused by touching the conductive part of the LED tube lamp which is incorrectly installed on the lamp socket or holder can be efficiently avoided.

Referring to FIG. **15**B, a block diagram of an installation detection module in accordance with certain embodiments is illustrated. The installation detection module includes a switch circuit **2580**, a detection pulse generating module **2540**, a detection result latching circuit **2560**, and a detection determining circuit **2570**. Certain of these circuits or modules may be referred to as first, second, third, etc., circuits as a naming convention to differentiate them from each other.

The detection determining circuit **2570** is coupled to and detects the signal between the installation detection terminals **2521** (through a switch circuit coupling terminal **2581** and the switch circuit **2580**) and **2522**. The detection determining circuit **2570** is also coupled to the detection result latching circuit **2560** via a detection result terminal **2571** to transmit the detection result signal to the detection result latching circuit **2560**. The detection determining circuit **2570** may be configured to detect a current passing through terminals **2521** and **2522** (e.g., to detect whether the current is above or below a specific current value).

The detection pulse generating module **2540** is coupled to the detection result latching circuit **2560** via a pulse signal output terminal **2541**, and generates a pulse signal to inform the detection result latching circuit **2560** of a time point for latching (storing) the detection result. For example, the detection pulse generating module **2540** may be a circuit configured to generate a signal that causes a latching circuit, such as the detection result latching circuit **2560** to enter and remain in a state that corresponds to one of a conducting state or a cut-off state for the LED tube lamp. The detection result latching circuit **2560** stores the detection result according to the detection result signal (or detection result signal and pulse signal), and transmits or provides the detection result to the switch circuit **2580** coupled to the detection result latching circuit **2560** via a detection result latching terminal **2561**. The switch circuit **2580** controls the state between conducting or cut off between the installation detection terminals **2521** and **2522** according to the detection result.

In some embodiments, the detection pulse generating module **2540** may be referred to as a first circuit **2540**, the detection result latching circuit **2560** may be referred to as a second circuit **2560**, the switch circuit **2580** may be referred to as a third circuit **2580**, the detection determining circuit **2570** may be referred to as a fourth circuit **2570**, the switch circuit coupling terminal **2581** may be referred to as a first terminal **2581** and the detection result terminal **2571** may be referred to as a second terminal **2571**, the pulse signal output terminal **2541** may be referred to as a third terminal **2541**, the detection result latching terminal **2561** may be referred to as a fourth terminal **2561**, the installation detection terminal **2521** may be referred to as a first installation detection terminal **2521**, and the installation detection terminal **2522** may be referred to as a second installation detection terminal **2522**. In this exemplary embodiment, the fourth circuit **2570** is coupled to the third circuit **2580** and the second circuit **2560** via the first terminal **2581** and the second terminal **2571**, respectively, the second circuit **2560** is also coupled to the first circuit **2540** and the third circuit **2580** via the third terminal **2541** and the fourth terminal **2561**, respectively.

In some embodiments, the fourth circuit **2570** is configured for detecting a signal between the first installation detection terminal **2521** and the second installation detection terminal **2522** through the first terminal **2581** and the third circuit **2580**. For example, because of the above configuration, the fourth circuit **2570** is capable of detecting and determining whether a current passing through the first installation detection terminal **2521** and the second installation detection terminal **2522** is below or above a predetermined current value and transmitting or providing a detection result signal to the second circuit **2560** via the second terminal **2571**.

In some embodiments, the first circuit **2540** generates a pulse signal through the second circuit **2560** to make the third circuit **2580** working in a conducting state during the pulse signal. Meanwhile, as a result, the power loop of the LED tube lamp between the installation detection terminals **2521** and **2522** is thus conducting as well. The fourth circuit **2570** detects a sampling signal on the power loop and generates a signal based on a detection result to inform the second circuit **2560** of a time point for latching (storing) the detection result received by the second circuit **2560** from the fourth circuit **2570**. For example, the fourth circuit **2570** may be a circuit configured to generate a signal that causes a latching circuit, such as the second circuit **2560** to enter and remain in a state that corresponds to one of a conducting state or a cut-off state for the LED tube lamp. The second circuit **2560** stores the detection result according to the detection result signal (or detection result signal and pulse signal), and transmits or provides the detection result to the third circuit **2580** coupled to the second circuit **2560** via the fourth terminal **2561**. The third circuit **2580** receives the detection result transmitted from the second circuit **2560** and controls the state between conducting or cut off between the installation detection terminals **2521** and **2522** according to the detection result. It should be noted that the labels "first," "second," "third," etc., described in connection with these embodiments can be interchangeable and are merely used here in order to more easily differentiate the different circuits, nodes, and other components from each other.

Referring to FIG. **15**C, a block diagram of a detection pulse generating module in accordance with certain embodiments is illustrated. A detection pulse generating module **2640** may be a circuit that includes multiple capacitors **2642**, **2645**, and **2646**, multiple resistors **2643**, **2647**, and **2648**, two buffers **2644** and **2651**, an inverter **2650**, a diode **2649**, and an OR gate **2652**. The capacitor **2642** may be referred to as a first capacitor **2642**, the capacitor **2645** may be referred to as a second capacitor **2645**, and the capacitor **2646** may be referred to as a third capacitor **2646**. The resistor **2643** may be referred to as a first resistor **2643**, the resistor **2647** may be referred to as a second resistor **2647**, and the resistor **2648** may be referred to as a third resistor **2648**. The buffer **2644** may be referred to as a first buffer **2644** and the buffer **2651** may be referred to as a second buffer **2651**. The diode **2649** may be referred to as a first diode **2649** and the OR gate **2652** may be referred to as a first OR gate **2652**. With use or operation, the capacitor **2642** and the resistor **2643** connect in series between a driving voltage (e.g., a driving voltage source, which may be a node of a power supply), such as VCC usually defined as a high logic level voltage, and a reference voltage (or potential), such as ground potential in this embodiment. The connection node between the capacitor **2642** and the resistor **2643** is coupled to an input terminal of the buffer **2644**. In this exemplary embodiment, the buffer **2644** includes two inverters connected in series between an input terminal and an output terminal of the buffer **2644**. The resistor **2647** is coupled between the driving voltage, e.g., VCC, and an input terminal of the inverter **2650**. The resistor **2648** is coupled between an input terminal of the buffer **2651** and the reference voltage, e.g. ground potential in this embodiment. An anode of the diode **2649** is grounded and a cathode of the diode **2649** is coupled to the input terminal of the buffer **2651**. First ends of the capacitors **2645** and **2646** are jointly coupled to an output terminal of the buffer **2644**, and second, opposite ends of the capacitors **2645** and **2646** are respectively coupled to the input terminal of the inverter **2650** and the input terminal of the buffer **2651**. In this exemplary embodiment, the buffer **2651** includes two inverters connected in series between an input terminal and an output terminal of the buffer **2651**. An output terminal of the inverter **2650** and an output terminal of the buffer **2651** are coupled to two input terminals of the OR gate **2652**. According to certain embodiments, the voltage (or potential) for "high logic level" and "low logic level" mentioned in this specification are all relative to another voltage (or potential) or a certain reference voltage (or potential) in circuits, and further may be described as "logic high logic level" and "logic low logic level."

When an end cap of an LED tube lamp is inserted into a lamp socket and the other end cap thereof is electrically coupled to a human body, or when both end caps of the LED tube lamp are inserted into the lamp socket, the LED tube lamp is conductive with electricity. At this moment, the installation detection module (e.g., the installation detection module **2520** as illustrated in FIG. **15**A) enters a detection stage. The voltage on the connection node of the capacitor **2642** and the resistor **2643** is high initially (equals to the driving voltage, VCC) and decreases with time to zero finally. The input terminal of the buffer **2644** is coupled to the connection node of the capacitor **2642** and the resistor **2643**, so the buffer **2644** outputs a high logic level signal at the beginning and changes to output a low logic level signal when the voltage on the connection node of the capacitor **2642** and the resistor **2643** decreases to a low logic trigger logic level. As a result, the buffer **2644** is configured to produce an input pulse signal and then remain in a low logic level thereafter (stops outputting the input pulse signal.) The width for the input pulse signal may be described as equal to one (initial setting) time period, which is determined by the capacitance value of the capacitor **2642** and the resistance value of the resistor **2643**.

Next, the operations for the buffer **2644** to produce the pulse signal with the initial setting time period will be described below. Since the voltage on a first end of the capacitor **2645** and on a first end of the resistor **2647** is equal to the driving voltage VCC, the voltage on the connection node of both of them is also a high logic level. The first end of the resistor **2648** is grounded and the first end of the capacitor **2646** receives the input pulse signal from the buffer **2644**, so the connection node of the capacitor **2646** and the resistor **2648** has a high logic level voltage at the beginning but this voltage decreases with time to zero (in the meantime, the capacitor stores the voltage being equal to or approaching the driving voltage VCC.) Accordingly, initially the inverter **2650** outputs a low logic level signal and the buffer **2651** outputs a high logic level signal, and hence the OR gate **2652** outputs a high logic level signal (a first pulse signal) at the pulse signal output terminal **2541**. At this moment, the detection result latching circuit **2560** (as illustrated in FIG. **15**B) stores the detection result for the first time according to the detection result signal received from the detection determining circuit **2570** (as illustrated in FIG. **15**B) and the pulse signal generated at the pulse signal output terminal **2541**. During that initial pulse time period, as illustrated in FIG. **15**B, the detection pulse generating module **2540** outputs a high logic level signal, which results in the detection result latching circuit **2560** outputting the result of that high logic level signal.

When the voltage on the connection node of the capacitor **2646** and the resistor **2648** decreases to the low logic trigger logic level, the buffer **2651** changes to output a low logic level signal to make the OR gate **2652** output a low logic level signal at the pulse signal output terminal **2541** (stops outputting the first pulse signal.) The width of the first pulse signal output from the OR gate **2652** is determined by the capacitance value of the capacitor **2646** and the resistance value of the resistor **2648**.

The operation after the buffer **2644** stops outputting the pulse signal is described as below. For example, the operation may be initially in an operating stage. Since the capacitor **2646** stores the voltage being almost equal to the driving voltage VCC, and when the buffer **2644** instantaneously changes its output from a high logic level signal to a low logic level signal, the voltage on the connection node of the capacitor **2646** and the resistor **2648** is below zero but will be pulled up to zero by the diode **2649** rapidly charging the capacitor **2646**. Therefore, the buffer **2651** still outputs a low logic level signal.

In some embodiments, when the buffer **2644** instantaneously changes its output from a high logic level signal to a low logic level signal, the voltage on the one end of the capacitor **2645** also changes from the driving voltage VCC to zero instantly. This makes the connection node of the capacitor **2645** and the resistor **2647** have a low logic level signal. At this moment, the output of the inverter **2650** changes to a high logic level signal to make the OR gate output a high logic level signal (a second pulse signal) at the pulse signal output terminal **2541**. The detection result latching circuit **2560** as illustrated in FIG. **15**B stores the detection result for a second time according to the detection result signal received from the detection determining circuit **2570** (as illustrated in FIG. **15**B) and the pulse signal generated at the pulse signal output terminal **2541**. Next, the driving voltage VCC charges the capacitor **2645** through the resistor **2647** to make the voltage on the connection node of the capacitor **2645** and the resistor **2647** increase with time to the driving voltage VCC. When the voltage on the connection node of the capacitor **2645** and the resistor **2647** increases to reach a high logic trigger logic level, the inverter **2650** outputs a low logic level signal again to make the OR gate **2652** stop outputting the second pulse signal. The width of the second pulse signal is determined by the capacitance value of the capacitor **2645** and the resistance value of the resistor **2647**.

As those mentioned above, in certain embodiments, the detection pulse generating module **2640** generates two high logic level pulse signals in the detection stage, which are the first pulse signal and the second pulse signal. These pulse signals are output from the pulse signal output terminal **2541**. Moreover, there is an interval with a defined time between the first and second pulse signals (e.g., an opposite-logic signal, which may have a low logic level when the pulse signals have a high logic level), and the defined time is determined by the capacitance value of the capacitor **2642** and the resistance value of the resistor **2643**.

From the detection stage entering the operating stage, the detection pulse generating module **2640** does not produce the pulse signal any more, and keeps the pulse signal output terminal **2541** on a low logic level potential. As described herein, the operating stage is the stage following the detection stage (e.g., following the time after the second pulse signal ends). The operating stage occurs when the LED tube lamp is at least partly connected to a power source, such as provided in a lamp socket. For example, the operating stage may occur when part of the LED tube lamp, such as only one side of the LED tube lamp, is properly connected to one side of a lamp socket, and part of the LED tube lamp is either connected to a high impedance, such as a person, and/or is improperly connected to the other side of the lamp socket (e.g., is misaligned so that the metal contacts in the socket do not contact metal contacts in the LED tube lamp). The operating stage may also occur when the entire LED tube lamp is properly connected to the lamp socket.

Referring to FIG. **15**D, a detection determining circuit in accordance with certain embodiments is illustrated. An exemplary detection determining circuit **2670** includes a comparator **2671** and a resistor **2672**. The comparator **2671** may also be referred to as a first comparator **2671** and the resistor **2672** may also be referred to as a fifth resistor **2672**. A negative input terminal of the comparator **2671** receives a reference logic level signal (or a reference voltage) Vref, a positive input terminal thereof is grounded through the resistor **2672** and is also coupled to a switch circuit coupling terminal **2581**. Referring to FIGS. **15**B and **15**D, the signal flowing into the switch circuit **2580** from the installation detection terminal **2521** outputs to the switch circuit coupling terminal **2581** to the resistor **2672**. When the current of the signal passing through the resistor **2672** reaches a certain level (for example, bigger than or equal to a defined current for installation, (e.g. 2 A) and this makes the voltage on the resistor **2672** higher than the reference voltage Vref (referring to two end caps inserted into the lamp socket,) the comparator **2671** produces a high logic level detection result signal and outputs it to the detection result terminal **2571**. For example, when an LED tube lamp is correctly installed on a lamp socket, the comparator **2671** outputs a high logic level detection result signal at the detection result terminal **2571**, whereas the comparator **2671** generates a low logic level detection result signal and outputs it to the detection result terminal **2571** when a current passing through the resistor **2672** is insufficient to make the voltage on the resistor **2672** higher than the reference voltage Vref (referring to only one end cap inserted into the lamp socket.) Therefore, in some embodiments, when the LED tube lamp is incorrectly installed on the lamp socket or one end cap thereof is inserted into the lamp socket but the other one is grounded by an object such as a human body, the current will be too small to make the comparator **2671** output a high logic level detection result signal to the detection result terminal **2571**.

Referring to FIG. **15**E, a schematic detection result latching circuit according to some embodiments of the present invention is illustrated. A detection result latching circuit **2660** includes a D flip-flop **2661**, a resistor **2662**, and an OR gate **2663**. The D flip-flop **2661** may also be referred to as a first D flip-flop **2661**, the resistor **2662** may also be referred to as a fourth resistor **2662**, and the OR gate **2663** may also be referred to as a second OR gate **2663**. The D flip-flop **2661** has a CLK input terminal coupled to a detection result terminal **2571**, and a D input terminal coupled to a driving voltage VCC. When the detection result terminal **2571** first outputs a low logic level detection result signal, the D flip-flop **2661** initially outputs a low logic level signal at a Q output terminal thereof, but the D flip-flop **2661** outputs a high logic level signal at the Q output terminal thereof when the detection result terminal **2571** outputs a high logic level detection result signal. The resistor **2662** is coupled between the Q output terminal of the D flip-flop **2661** and a reference voltage, such as ground potential. When the OR gate **2663** receives the first or second pulse signals from the pulse signal output terminal **2541** or receives a high logic level signal from the Q output terminal of the D flip-flop **2661**, the OR gate **2663** outputs a high logic level detection result latching signal at a detection result latching terminal **2561**. The detection pulse generating module **2640** only in the detection stage outputs the first and the second pulse signals to make the OR gate **2663** output the high logic level detection result latching signal, and thus the D flip-flop **2661** decides the detection result latching signal to be the high logic level or the low logic level the rest of the time, e.g., including the operating stage after the detection stage. Accordingly, when the detection result terminal **2571** has no high logic level detection result signal, the D flip-flop **2661** keeps a low logic level signal at the Q output terminal to make the detection result latching terminal **2561** also keep a low logic level detection result latching signal in the detection stage. On the contrary, once the detection result terminal **2571** has a high logic level detection result signal, the D flip-flop **2661** outputs and keeps a high logic level signal (e.g., based on VCC) at the Q output terminal. In this way, the detection result latching terminal **2561** keeps a high logic level detection result latching signal in the operating stage as well.

Referring to FIG. **15**F, a schematic switch circuit according to some embodiments is illustrated. A switch circuit **2680** includes a transistor, such as a bipolar junction transistor (BJT) **2681**, as being a power transistor, which has the ability of dealing with high current/power and is suitable for the switch circuit. The BJT **2681** may also be referred to as a first transistor **2681**. The BJT **2681** has a collector coupled to an installation detection terminal **2521**, a base coupled to a detection result latching terminal **2561**, and an emitter coupled to a switch circuit coupling terminal **2581**. When the detection pulse generating module **2640** produces the first and second pulse signals, the BJT **2681** is in a transient conduction state. This allows the detection determining circuit **2670** to perform the detection for determining the detection result latching signal to be a high logic level or a low logic level. When the detection result latching circuit **2660** outputs a high logic level detection result latching signal at the detection result latching terminal **2561**, the BJT **2681** is in the conducting state to make the installation detection terminals **2521** and **2522** conducting. In contrast, when the detection result latching circuit **2660** outputs a low logic level detection result latching signal at the detection result latching terminal **2561** and the output from detection pulse generating module **2640** is a low logic level, the BJT **2681** is cut-off or in the blocking state to make the installation detection terminals **2521** and **2522** cut-off or blocking.

Since the external driving signal is an AC signal and in order to avoid the detection error resulting from the logic level of the external driving signal being just around zero when the detection determining circuit **2670** detects, the detection pulse generating module **2640** generates the first and second pulse signals to let the detection determining circuit **2670** perform two detections. So the issue of the logic level of the external driving signal being just around zero in a single detection can be avoided. In some cases, the time difference between the productions of the first and second pulse signals is not multiple times of half one cycle of the external driving signal. For example, it does not correspond to the multiple phase differences of 180 degrees of the external driving signal. In this way, when one of the first and second pulse signals is generated and unfortunately the external driving signal is around zero, it can be avoided that the external driving signal is again around zero when the other pulse signal is generated.

The time difference between the productions of the first and second pulse signals, for example, an interval with a defined time between both of them can be represented as following:

$$\text{the interval}=(X+Y)(T/2),$$

where T represents the cycle of an external driving signal, X is a natural number, 0<Y<1, with Y in some embodiments in the range of 0.05-0.95, and in some embodiments in the range of 0.15-0.85.

Furthermore, in order to avoid the installation detection module entering the detection stage from misjudgment resulting from the logic level of the driving voltage VCC being too small, the first pulse signal can be set to be produced when the driving voltage VCC reaches or is higher than a defined logic level. For example, in some embodiments, the detection determining circuit **2670** works after the driving voltage VCC reaching a high enough logic level in order to prevent the installation detection module from misjudgment due to an insufficient logic level.

According to the examples mentioned above, when one end cap of an LED tube lamp is inserted into a lamp socket and the other one floats or electrically couples to a human body or other grounded object, the detection determining circuit outputs a low logic level detection result signal because of high impedance. The detection result latching circuit stores the low logic level detection result signal based on the pulse signal of the detection pulse generating module, making it as the low logic level detection result latching signal, and keeps the detection result in the operating stage, without changing the logic value. In this way, the switch circuit keeps cutting-off or blocking instead of conducting continually. And further, the electric shock situation can be prevented and the requirement of safety standard can also be met. On the other hand, when two end caps of the LED tube lamp are correctly inserted into the lamp socket, the detection determining circuit outputs a high logic level detection result signal because the impedance of the circuit for the LED tube lamp itself is small. The detection result latching circuit stores the high logic level detection result signal based on the pulse signal of the detection pulse generating module, making it as the high logic level detection result latching signal, and keeps the detection result in the operating stage. So the switch circuit keeps conducting to make the LED tube lamp work normally in the operating stage.

In some embodiments, when one end cap of the LED tube lamp is inserted into the lamp socket and the other one floats or electrically couples to a human body, the detection determining circuit outputs a low logic level detection result signal to the detection result latching circuit, and then the detection pulse generating module outputs a low logic level signal to the detection result latching circuit to make the detection result latching circuit output a low logic level detection result latching signal to make the switch circuit cutting-off or blocking. As such, the switch circuit blocking makes the installation detection terminals, e.g. the first and second installation detection terminals, blocking. As a result, the LED tube lamp is in non-conducting or blocking state.

However, in some embodiments, when two end caps of the LED tube lamp are correctly inserted into the lamp socket, the detection determining circuit outputs a high logic level detection result signal to the detection result latching circuit to make the detection result latching circuit output a high logic level detection result latching signal to make the switch circuit conducting. As such, the switch circuit conducting makes the installation detection terminals, e.g. the first and second installation detection terminals, conducting. As a result, the LED tube lamp operates in a conducting state.

Thus, according to the operation of the installation detection module, a first circuit, upon connection of at least one end of the LED tube lamp to a lamp socket, generates and outputs two pulses, each having a pulse width, with a time period between the pulses. The first circuit may include various of the elements described above configured to output the pulses to a base of a transistor (e.g., a BJT transistor) that serves as a switch. The pulses occur during a detection stage for detecting whether the LED tube lamp is properly connected to a lamp socket. The timing of the pulses may be controlled based on the timing of various parts of the first circuit changing from high to low logic levels, or vice versa.

The pulses can be timed such that, during that detection stage time, if the LED tube lamp is properly connected to the lamp socket (e.g., both ends of the LED tube lamp are correctly connected to conductive terminals of the lamp socket), at least one of the pulse signals occurs when an AC current from a driving signal is at a non-zero level. For example, the pulse signals can occur at intervals that are different from half of the period of the AC signal. For example, respective start points or mid points of the pulse signals, or a time between an end of the first pulse signal and a beginning of the second pulse signal may be separated by an amount of time that is different from half of the period of the AC signal (e.g., it may be between 0.05 and 0.95 percent of a multiple of half of the period of the AC signal). During a pulse that occurs when the AC signal is at a non-zero level, a switch that receives the AC signal at the non-zero level may be turned on, causing a latch circuit to change states such that the switch remains permanently on so long as the LED tube lamp remains properly connected to the lamp socket. For example, the switch may be configured to turn on when each pulse is output from the first circuit. The latch circuit may be configured to change state only when the switch is on and the current output from the switch is above a threshold value, which may indicate a proper connection to a light socket. As a result, the LED tube lamp operates in a conducting state.

On the other hand, if both pulses occur when a driving signal at the LED tube lamp has a near-zero current level, or a current level below a particular threshold, then the state of the latch circuit is not changed, and so the switch is only on during the two pulses, but then remains permanently off after the pulses and after the detection mode is over. For example, the latch circuit can be configured to remain in its present state if the current output from the switch is below the threshold value. In this manner, the LED tube lamp remains in a non-conducting state, which prevents electric shock, even though part of the LED tube lamp is connected to an electrical power source.

It is worth noting that according to certain embodiments, the width of the pulse signal generated by the detection pulse generating module is between 10 μs to 1 ms, and it is used to make the switch circuit conducting for a short period when the LED tube lamp conducts instantaneously. In some embodiments, a pulse current is generated to pass through the detection determining circuit for detecting and determining. Since the pulse is for a short time and not for a long time, the electric shock situation will not occur. Furthermore, the detection result latching circuit also keeps the detection result during the operating stage (e.g., the operating stage being the period after the detection stage and during which part of the LED tube lamp is still connected to a power source), and no longer changes the detection result stored previously complying with the circuit state changing. A situation resulting from changing the detection result can thus be avoided. In some embodiments, the installation detection module, such as the switch circuit, the detection pulse generating module, the detection result latching circuit, and the detection determining circuit, could be integrated into a chip and then embedded in circuits for saving the circuit cost and layout space.

As discussed in the above examples, in some embodiments, an LED tube lamp includes an installation detection circuit comprising a first circuit configured to output two pulse signals, the first pulse signal output at a first time and the second pulse signal output at a second time after the first time, and a switch configured to receive an LED driving signal and to receive the two pulse signals, wherein the two pulse signals control turning on and off of the switch. The installation detection circuit may be configured to, during a detection stage, detect during each of the two pulse signals whether the LED tube lamp is properly connected to a lamp socket. When it is not detected during either pulse signal that the LED tube lamp is properly connected to the lamp socket, the switch may remain in an off state after the detection stage. When it is detected during at least one of the pulse signals that the LED tube lamp is properly connected to the lamp socket, the switch may remain in an on state after the detection stage. The two pulse signals may occur such that they are separated by a time different from a multiple of half of a period of the LED driving signal, and such that at least one of them does not occur when the LED driving signal has a current value of substantially zero. It should be noted that although a circuit for producing two pulse signals is described, the disclosure is not intended to be limiting as such. For example, a circuit may be implemented such that a plurality of pulse signals may occur, wherein at least two of the plurality of pulse signals are separated by a time different from a multiple of half of a period of the LED driving signal, and such that at least one of the plurality of pulse signals does not occur when the LED driving signal has a current value of substantially zero.

Referring to FIG. **15**G, an installation detection module according to an exemplary embodiment is illustrated. The installation detection module includes a detection pulse generating module **2740** (which may also be referred to as a detection pulse generating circuit or a first circuit), a detection result latching circuit **2760** (which may also be referred to as a second circuit), a switch circuit **2780** (which may also be referred to as a third circuit), and a detection determining circuit **2770** (which may also be referred to as a fourth circuit). The detection pulse generating module **2740** is coupled (e.g., electrically connected) to the detection result latching circuit **2760** via a path **2741**, and is configured to generate at least one pulse signal. A path as described herein may include a conductive line connecting between two components, circuits, or modules, and may include opposite ends of the conductive line connected to the respective components, circuits or modules. The detection result latching circuit **2760** is coupled (e.g., electrically connected) to the switch circuit **2780** via a path **2761**, and is configured to receive and output the pulse signal(s) from the detection pulse generating module **2740**. The switch circuit **2780** is coupled (e.g., electrically connected) to one end (e.g., a first installation detection terminal **2521**) of a power loop of an LED tube lamp and the detection determining circuit **2770**, and is configured to receive the pulse signal(s) output from the detection result latching circuit **2760**, and configured to conduct (or turn on) during the pulse signal(s) so as to cause the power loop of the LED tube lamp to be conducting. The detection determining circuit **2770** is coupled (e.g., electrically connected) to the switch circuit **2780**, the other end (e.g., a second installation detection terminal **2522**) of the power loop of the LED tube lamp and the detection result latching circuit **2760**, and is configured to detect at least one sampling signal on the power loop when the switch circuit **2780** and the power loop are conductive, so as to determine an installation state between the LED tube lamp and a lamp socket. The detection determining circuit **2770** is further configured to transmit detection result(s) to the detection result latching circuit **2760** for next control. In some embodiments, the detection pulse generating module **2740** is further coupled (e.g., electrically connected) to the output of the detection result latching circuit **2760** to control the time of the pulse signal (s).

In some embodiments, one end of a first path **2781** is coupled to a first node of the detection determining circuit **2770** and the opposite end of the first path **2781** is coupled to a first node of the switch circuit **2780**. In some embodiments, a second node of the detection determining circuit **2770** is coupled to the second installation detection terminal **2522** of the power loop and a second node of the switch circuit **2780** is coupled to the first installation detection terminal **2521** of the power loop. In some embodiments, one end of a second path **2771** is coupled to a third node of the detection determining circuit **2770** and the opposite end of the second path **2771** is coupled to a first node of the detection result latching circuit **2760**, one end of a third path **2741** is coupled to a second node of the detection result latching circuit **2760** and the opposite end of the third path **2741** is coupled to a first node of the detection pulse generating circuit **2740**. In some embodiments, one end of a fourth path **2761** is coupled to a third node of the switch circuit **2780** and the opposite end of the fourth path **2761** is coupled to a third node of the detection result latching circuit **2760**. In some embodiments, the fourth path **2761** is also coupled to a second node of the detection pulse generating circuit **2740**.

In some embodiments, the detection determining circuit **2770** is configured for detecting a signal between the first installation detection terminal **2521** and the second installation detection terminal **2522** through the first path **2781** and the switch circuit **2780**. For example, because of the above configuration, the detection determining circuit **2770** is capable of detecting and determining whether a current passing through the first installation detection terminal **2521** and the second installation detection terminal **2522** is below or above a predetermined current value and transmitting or providing a detection result signal to the detection result latching circuit **2760** via the second path **2771**.

In some embodiments, the detection pulse generating circuit **2740**, also referred to generally as a pulse generating circuit, generates a pulse signal through the detection result latching circuit **2760** to make the switch circuit **2780** remain in a conducting state during the pulse signal. For example, the pulse signal generated by the detection pulse generating circuit **2740** controls turning on the switch circuit **2780** which is coupled to the detection pulse generating circuit **2740**. As a result of maintaining a conducting state of the switch circuit **2780**, the power loop of the LED tube lamp between the installation detection terminals **2521** and **2522** is also maintain a conducting state. The detection determining circuit **2770** detects a sampling signal on the power loop and generates a signal based on a detection result to inform the detection result latching circuit **2760** of a time point for latching (storing) the detection result received by the detection result latching circuit **2760** from the detection determining circuit **2770**. For example, the detection determining circuit **2770** may be a circuit configured to generate a signal that causes a latching circuit, such as the detection result latching circuit **2760** to enter and remain in a state that corresponds to one of a conducting state (e.g., "on" state) or a cut-off state for the LED tube lamp. The detection result latching circuit **2760** stores the detection result according to the detection result signal (or detection result signal and pulse signal), and transmits or provides the detection result to the switch circuit **2780** coupled to the third node of the detection result latching circuit **2760** via the fourth path **2761**. The switch circuit **2780** receives the detection result transmitted from the detection result latching circuit **2760** via the third node of the switch circuit **2780** and controls the state between conducting or cut off between the installation detection terminals **2521** and **2522** according to the detection result. For example, when the detection determining circuit **2770** detects during the pulse signal that the LED tube lamp is not properly installed on the lamp socket, the pulse signal controls the switch circuit to remain in an off state to cause a power loop of the LED tube lamp to be open, and when the detection determining circuit **2770** detects during the pulse signal that the LED tube lamp is properly installed on the lamp socket, the pulse signal controls the switch circuit to remain in a conducting state to cause the power loop of the LED tube lamp to a maintain conducting state.

The detail circuit architecture and the entire operation thereof of each of the detection pulse generating module **2740** (or circuit), the detection result latching circuit **2760**, the switch circuit **2780**, and the detection determining circuit **2770** will be described below.

Referring to FIG. **15**H, a detection pulse generating module according to an exemplary embodiment is illustrated. The detection pulse generating module **2740** includes: a resistor **2742** (which also may be referred to as a sixth resistor), a capacitor **2743** (which also may be referred to as a fourth capacitor), a Schmitt trigger **2744**, a resistor **2745** (which also may be referred to as a seventh resistor), a transistor **2746** (which also may be referred to as a second transistor), and a resistor **2747** (which also may be referred to as an eighth resistor).

In some embodiments, one end of the resistor **2742** is connected to a driving signal, for example, Vcc, and the other end of the resistor **2742** is connected to one end of the capacitor **2743**. The other end of the capacitor **2743** is connected to a ground node. In some embodiments, the Schmitt trigger **2744** has an input end and an output end, the input end connected to a connection node of the resistor **2742** and the capacitor **2743**, the output end connected to the detection result latching circuit **2760** via the third path **2741** (FIG. **15**G). In some embodiments, one end of the resistor **2745** is connected to the connection node of the resistor **2742** and the capacitor **2743** and the other end of the resistor **2745** is connected to a collector of the transistor **2746**. An emitter of the transistor **2746** is connected to a ground node. In some embodiments, one end of the resistor **2747** is connected to a base of the transistor **2746** and the other end of the resistor **2747** is connected to the detection result latching circuit **2760** (FIG. **15**G) and the switch circuit **2780** (FIG. **15**G) via the fourth path **2761**. In certain embodiments, the detection pulse generating module **2740** further includes: a Zener diode **2748**, having an anode and a cathode, the anode connected to the other end of the capacitor **2743** to the ground, the cathode connected to the end of the capacitor **2743** (the connection node of the resistor **2742** and the capacitor **2743**).

Referring to FIG. **15**I, a detection result latching circuit according to an exemplary embodiment is illustrated. The detection result latching circuit **2760** includes: a D flip-flop **2762** (which also may be referred to as a second D flip-flop), having a data input end D, a clock input end CLK, and an output end Q, the data input end D connected to the driving signal mentioned above (e.g., Vcc), the clock input end CLK connected to the detection determining circuit **2770** (FIG. **15**G); and an OR gate **2763** (which also may be referred to as a third OR gate), having a first input end, a second input end, and an output end, the first input end connected to the output end of the Schmitt trigger **2744** (FIG. **15**H), the second input end connected to the output end Q of the D flip-flop **2762**, the output end of the OR gate **2763** connected to the other end of the resistor **2747** (FIG. **15**H) and the switch circuit **2780** (FIG. **15**G).

Referring to FIG. **15**J, a switch circuit according to an exemplary embodiment is illustrated. The switch circuit **2780** includes: a transistor **2782** (which also may be referred to as a third transistor), having a base, a collector, and an emitter, the base connected to the output of the OR gate **2763** via the fourth path **2761** (FIG. **15**I), the collector connected to one end of the power loop, such as the first installation detection terminal **2521**, the emitter connected to the detection determining circuit **2770** (FIG. **15**G). In some embodiments, the transistor **2782** may be replaced by other equivalently electronic parts, e.g., a MOSFET.

Referring to FIG. **15**K, a detection determining circuit according to an exemplary embodiment is illustrated. The detection determining circuit **2770** includes: a resistor **2774** (which also may be referred to as a ninth resistor), one end of the resistor **2774** connected to the emitter of the transistor **2782** (FIG. **15**J), the other end of the resistor **2774** connected to the other end of the power loop, such as the second installation detection terminal **2522**; a diode **2775** (which also may be referred to as a second diode), having an anode and a cathode, the anode connected to an end of the resistor **2744** that is not connected to a ground node; a comparator **2772** (which also may be referred to as a second comparator), having a first input end, a second input end, and an output end; a comparator **2773** (which also may be referred to as a third comparator), having a first input end, a second input end, and an output end; a resistor **2776** (which also may be referred to as a tenth resistor); a resistor **2777** (which also may be referred to as an eleventh resistor); and a capacitor **2778** (which also may be referred to as a fifth capacitor).

In some embodiments, the first input end of the comparator **2772** is connected to a predefined signal, for example, a reference voltage, Vref=1.3V, but the reference voltage value is not limited thereto, the second input end of the comparator **2772** is connected to the cathode of the diode **2775**, and the output end of the comparator **2772** is connected to the clock input end of the D flip-flop **2762** (FIG. **15**I). In some embodiments, the first input end of the comparator **2773** is connected to the cathode of the diode **2775**, the second input end of the comparator **2773** is connected to another predefined signal, for example, a reference voltage, Vref=0.3V, but the reference voltage value is not limited thereto, and the output end of the comparator **2773** is connected to the clock input end of the D flip-flop **2762** (FIG. **15**I). In some embodiments, one end of the resistor **2776** is connected to the driving signal mentioned above (e.g., Vcc) and the other end of the resistor **2776** is connected to the second input end of the comparator **2772** and one end of the resistor **2777** that is not connected to a ground node and the other end of the resistor **2777** is connected to the ground node. In some embodiments, the capacitor **2778** is connected to the resistor **2777** in parallel. In certain embodiments, the diode **2775**, the comparator **2773**, the resistors **2776** and **2777**, and the capacitor **2778** may be omitted, and the second input end of the comparator **2772** may be directly connected to the end of the resistor **2774** (e.g., the end of the resistor **2774** that is not connected to the ground node) when the diode **2775** is omitted. In certain embodiments, the resistor **2774** may include two resistors connected in parallel based on the consideration of power consumption having an equivalent resistance value ranging from about 0.1 ohm to about 5 ohm.

In some embodiments, some parts of the installation detection module may be integrated into an integrated circuit (IC) in order to provide reduced circuit layout space resulting in reduced manufacturing cost of the circuit. For example, the Schmitt trigger **2744** of the detection pulse generating module **2740**, the detection result latching circuit **2760**, and the two comparators **2772** and **2773** of the detection determining circuit **2770** may be integrated into an IC, but the disclosure is not limited thereto.

An operation of the installation detection module will be described in more detail in accordance with some example embodiments. In one exemplary embodiment, the capacitor voltage may not mutate; the voltage of the capacitor in the power loop of the LED tube lamp before the power loop being conductive is zero and the capacitor's transient response may appear to have a short-circuit condition; when the LED tube lamp is correctly installed to the lamp socket, the power loop of the LED tube lamp in transient response may have a smaller current-limiting resistance and a bigger peak current; and when the LED tube lamp is incorrectly installed to the lamp socket, the power loop of the LED tube lamp in transient response may have a bigger current-limiting resistance and a smaller peak current. This embodiment may also meet the UL standard to make the leakage current of the LED tube lamp less than 5 MIU. The following table illustrates the current comparison in a case when the LED tube lamp works normally (e.g., when the two end caps of the LED tube lamp are correctly installed to the lamp socket) and in a case when the LED tube lamp is incorrectly installed to the lamp socket (e.g., when one end cap of the LED tube lamp is installed to the lamp socket but the other one is touched by a human body).

	Correct installation	Incorrect installation
Maximum transient current		$i_{pk\_max} = \frac{V_{in\_pk}}{R_{fuse}+500} = \frac{305\times1.414}{10+500} = 845\text{ mA}$
Minimum transient current	$i_{pk\_max} = \frac{\Delta V_{in}}{R_{fuse}} = \frac{50}{10} = 5\text{A}$	

As illustrated in the above table, in the part of the denominator: R_{fuse} represents the resistance of the fuse of the LED tube lamp. For example, 10 ohm may be used, but the disclosure is not limited thereto, as resistance value for R_{fuse} in calculating the minimum transient current i_{pk_min} and 510 ohm may be used as resistance value for R_{fuse} in calculating the maximum transient current i_{pk_max} (an additional 500 ohms is used to emulate the conductive resistance of human body in transient response). In the part of the numerator: maximum voltage from the root-mean-square voltage (Vmax=Vrms*1.414=305*1.414) is used in calculating the maximum transient current i_{pk_max} and minimum voltage difference, for example, 50V (but the disclosure is not limited thereto) is used in calculating the minimum transient current i_{pk_min}. Accordingly, when the LED tube lamp is correctly installed to the lamp socket (e.g., when two end caps of the LED tube lamp are installed to the lamp socket correctly) and works normally, its minimum transient current is 5 A. But, when the LED tube lamp is incorrectly installed to the lamp socket (e.g., when one end cap is installed to the lamp socket but the other one is touched by human body), its maximum transient current is only 845 mA. Therefore, certain examples of the disclosed embodiments use the current which passes transient response and flows through the capacitor in the LED power loop, such as the capacitor of the filtering circuit, to detect and determine the installation state between the LED tube lamp and the lamp socket. For example, such embodiments may detect whether the LED tube lamp is correctly installed to the lamp socket. Certain examples of the disclosed embodiments further provide a protection mechanism to protect the user from electric shock caused by touching the conductive part of the LED tube lamp which is incorrectly installed to the lamp socket. The embodiments mentioned above are used to illustrate certain aspects of the disclosed invention but the disclosure is not limited thereto.

Further, referring to FIG. **15**G again, in some embodiments, when an LED tube lamp is being installed to a lamp socket, after a period (e.g., the period utilized to determine the cycle of a pulse signal), the detection pulse generating module **2740** outputs a first high level voltage rising from a first low level voltage to the detection result latching circuit **2760** through a path **2741** (also referred to as a third path). The detection result latching circuit **2760** receives the first high level voltage, and then simultaneously outputs a second high level voltage to the switch circuit **2780** and the detection pulse generating module **2740** through a path **2761** (also referred to as a fourth path). In some embodiments, when the switch circuit **2780** receives the second high level voltage, the switch circuit **2780** conducts to cause the power loop of the LED tube lamp to be conducting as well. In this exemplary embodiment, the power loop at least includes the first installation detection terminal **2521**, the switch circuit **2780**, the path **2781** (also referred to as a first path), the detection determining circuit **2770**, and the second installation detection terminal **2522**. In the meantime, the detection pulse generating module **2740** receives the second high level voltage from the detection result latching circuit **2760**, and after a period (e.g., the period utilized to determine the width (or period) of pulse signal), its output from the first high level voltage falls back to the first low level voltage (the first time of the first low level voltage, the first high level voltage, and the second time of the first low level voltage form a first pulse signal). In some embodiments, when the power loop of the LED tube lamp is conductive, the detection determining circuit **2770** detects a first sampling signal, such as a voltage signal, on the power loop. When the first sampling signal is greater than or equal to a predefined signal, such as a reference voltage, the installation detection module determines that the LED tube lamp is correctly installed to the lamp socket according to the application principle of this disclosed embodiments described above. Therefore, the detection determining circuit **2770** included in the installation detection module outputs a third high level voltage (also referred to as a first high level signal) to the detection result latching circuit **2760** through a path **2771** (also referred to as a second path). The detection result latching circuit **2760** receives the third high level voltage (also referred to as the first high level signal) and continues to output a second high level voltage (also referred to as a second high level signal) to the switch circuit **2780**. The switch circuit **2780** receives the second high level voltage (also referred to as the second high level signal) and maintains conducting state to cause the power loop to remain conducting. The detection pulse generating module **2740** does not generate any pulse signal while the power loop remains conductive.

However, in some embodiments, when the first sampling signal is smaller than the predefined signal, the installation detection module, according to certain exemplary embodiments as described above, determines that the LED tube lamp has not been correctly installed to the lamp socket. Therefore, the detection determining circuit **2770** outputs a third low level voltage (also referred to as a first low level signal) to the detection result latching circuit **2760**. The detection result latching circuit **2760** receives the third low level voltage (also referred to as the first low level signal) and continues to output a second low level voltage (also referred to as a second low level signal) to the switch circuit **2780**. The switch circuit **2780** receives the second low level voltage (also referred to as the second low level signal) and then keeps blocking to cause the power loop to remain open. Accordingly, the occurrence of electric shock caused by touching the conductive part of the LED tube lamp which is incorrectly installed on the lamp socket can be sufficiently avoided.

In some embodiments, when the power loop of the LED tube lamp remains open for a period (a period that represents the cycle of pulse signal), the detection pulse generating module **2740** outputs the first high level voltage rising from the first low level voltage to the detection result latching circuit **2760** through the path **2741** once more. The detection result latching circuit **2760** receives the first high level voltage, and then simultaneously outputs a second high level voltage to the switch circuit **2780** and the detection pulse generating module **2740**. In some embodiments, when the switch circuit **2780** receives the second high level voltage, the switch circuit **2780** conducts again to cause the power loop of the LED tube lamp (in this exemplary embodiment, the power loop at least includes the first installation detection terminal **2521**, the switch circuit **2780**, the path **2781**, the detection determining circuit **2770**, and the second installation detection terminal **2522**) to be conducting as well. In the meantime, the detection pulse generating module **2740** receives the second high level voltage from the detection result latching circuit **2760**, and after a period (a period that is utilized to determine the width (or period) of pulse signal), its output from the first high level voltage falls back to the first low level voltage (the third time of the first low level voltage, the second time of the first high level voltage, and the fourth time of the first low level voltage form a second pulse signal). In some embodiments, when the power loop of the LED tube lamp is conductive again, the detection determining circuit **2770** also detects a second sampling signal, such as a voltage signal, on the power loop yet again. When the second sampling signal is greater than or equal to the predefined signal, the installation detection module determines, according to certain exemplary embodiments described above, that the LED tube lamp is correctly installed to the lamp socket. Therefore, the detection determining circuit **2770** outputs a third high level voltage (also referred to as a first high level signal) to the detection result latching circuit **2760** through the path **2771**. The detection result latching circuit **2760** receives the third high level voltage (also referred to as the first high level signal) and continues to output a second high level voltage (also referred to as a second high level signal) to the switch circuit **2780**. The switch circuit **2780** receives the second high level voltage (also referred to as the second high level signal) and maintains a conducting state to cause the power loop to remain conducting. The detection pulse generating module **2740** does not generate any pulse signal while the power loop remains conductive.

In some embodiments, when the second sampling signal is smaller than the predefined signal, the installation detection module determines, according to certain exemplary embodiments described above, that the LED tube lamp has not been correctly installed to the lamp socket. Therefore, the detection determining circuit **2770** outputs the third low level voltage (also referred to as the first low level signal) to the detection result latching circuit **2760**. The detection result latching circuit **2760** receives the third low level voltage (also referred to as the first low level signal) and continues to output the second low level voltage (also referred to as the second low level signal) to the switch circuit **2780**. The switch circuit **2780** receives the second low level voltage (also referred to as the second low level signal) and then keeps blocking to cause the power loop to remain open.

Next, referring to FIG. **15**H-FIG. **15**K at the same time, in some embodiments when an LED tube lamp is being installed to a lamp socket, the capacitor **2743** is charged by the driving signal, for example, Vcc, through the resistor **2742**. And when the voltage of the capacitor **2743** rises enough to trigger the Schmitt trigger **2744**, the Schmitt trigger **2744** outputs a first high level voltage rising from a first low level voltage in an initial state to an input end of the OR gate **2763**. After the OR gate **2763** receives the first high level voltage from the Schmitt trigger **2744**, the OR gate **2763** outputs a second high level voltage to the base of the transistor **2782** and the resistor **2747**. When the base of the transistor **2782** receives the second high level voltage from the OR gate **2763**, the collector and the emitter of the transistor **2782** are conducting to further cause the power loop of the LED tube lamp (in this exemplary embodiment, the power loop at least includes the first installation detection terminal **2521**, the transistor **2782**, the resistor **2744**, and the second installation detection terminal **2522**) to be conducting as well. In the meantime, the base of the transistor **2746** receives the second high level voltage from the OR gate **2763** through the resistor **2747**, and then the collector and the emitter of the transistor **2746** are conductive and grounded to cause the voltage of the capacitor **2743** to be discharged to the ground through the resistor **2745**. In some embodiments, when the voltage of the capacitor **2743** is not enough to trigger the Schmitt trigger **2744**, the Schmitt trigger **2744** outputs the first low level voltage falling from the first high level voltage (a first instance of a first low level voltage at a first time, followed by a first high level voltage, followed by a second instance of the first low level voltage at a second time form a first pulse signal). When the power loop of the LED tube lamp is conductive, the current passing through the capacitor in the power loop, such as, the capacitor of the filtering circuit, by transient response flows through the transistor **2782** and the resistor **2774** and forms a voltage signal on the resistor **2774**. The voltage signal is compared to a reference voltage, for example, 1.3V, but the reference voltage is not limited thereto, by the comparator **2772**. When the voltage signal is greater than and/or equal to the reference voltage, the comparator **2772** outputs a third high level voltage to the clock input end CLK of the D flip-flop **2762**. In the meantime, since the data input end D of the D flip-flop **2762** is connected to the driving signal, the D flip-flop **2762** outputs a high level voltage (at its output end Q) to another input end of the OR gate **2763**. This causes the OR gate **2763** to keep outputting the second high level voltage to the base of the transistor **2782**, and further results in the transistor **2782** and the power loop of the LED tube lamp remaining in a conducting state. Besides, since the OR gate **2763** keeps outputting the second high level voltage to cause the transistor **2746** to be conducting to the ground, the capacitor **2743** is unable to reach an enough voltage to trigger the Schmitt trigger **2744**.

However, when the voltage signal on the resistor **2774** is smaller than the reference voltage, the comparator **2772** outputs a third low level voltage to the clock input end CLK of the D flip-flop **2762**. In the meantime, since the initial output of the D flip-flop **2762** is a low level voltage (e.g., zero voltage), the D flip-flop **2762** outputs a low level voltage (at its output end Q) to the other input end of the OR gate **2763**. Moreover, the Schmitt trigger **2744** connected by the input end of the OR gate **2763** also restores outputting the first low level voltage, the OR gate **2763** thus keeps outputting the second low level voltage to the base of the transistor **2782**, and further results in the transistor **2782** to remain in a blocking state (or an off state) and the power loop of the LED tube lamp to remain in an open state. Still, since the OR gate **2763** keeps outputting the second low level voltage to cause the transistor **2764** to remain in a blocking state (or an off state), the capacitor **2743** is charged by the driving signal through the resistor **2742** once again for next (pulse signal) detection.

In some embodiments, the cycle (or interval) of the pulse signal is determined by the values of the resistor **2742** and the capacitor **2743**. In certain cases, the cycle of the pulse signal may include a value ranging from about 3 milliseconds to about 500 milliseconds or may be ranging from about 20 milliseconds to about 50 milliseconds. In some embodiments, the width (or period) of the pulse signal is determined by the values of the resistor **2745** and the capacitor **2743**. In certain cases, the width of the pulse signal may include a value ranging from about 1 microsecond to about 100 microseconds or may be ranging from about 10 microseconds to about 20 microseconds. The Zener diode **2748** provides a protection function but it may be omitted in certain cases. The resistor **2744** may include two resistors connected in parallel based on the consideration of power consumption in certain cases, and its equivalent resistance may include a value ranging from about 0.1 ohm to about 5 ohm. The resistors **2776** and **2777** provides the function of voltage division to make the input of the comparator **2773** bigger than the reference voltage, such as 0.3V, but the value of the reference voltage is not limited thereto. The capacitor **2778** provides the functions of regulation and filtering. The diode **2775** limits the signal to be transmitted in one way. In addition, the installation detection module disclosed by the example embodiments may also be adapted to other types of LED lighting equipment with dual-end power supply, e.g., the LED lamp directly using commercial power as its external driving signal, the LED lamp using the signal outputted from the ballast as its external driving signal, etc. However, the invention is not limited to the above example embodiments.

According to some embodiments, the present invention further provides a detection method adopted by a light-emitting device (LED) tube lamp for preventing a user from electric shock when the LED tube lamp is being installed on a lamp socket. The detection method includes: generating a first pulse signal by a detection pulse generating module, wherein the detection pulse generating module is configured in the LED tube lamp; receiving the first pulse signal through a detection result latching circuit by a switch circuit, and making the switch circuit conducting during the first pulse signal to cause a power loop of the LED tube lamp to be conducting, wherein the switch circuit is on the power loop; and detecting a first sampling signal on the power loop by a detection determining circuit as the power loop being conductive, and comparing the first sampling signal with a predefined signal, wherein when the first sampling signal is greater than or equal to the predefined signal, the detection method further includes: outputting a first high level signal by the detection determining circuit; receiving the first high level signal by the detection result latching circuit and outputting a second high level signal; and receiving the second high level signal by the switch circuit and conducting to cause the power loop to remain conductive.

In some embodiments, when the first sampling signal is smaller than the predefined signal, the detection method further includes: outputting a first low level signal by the detection determining circuit; receiving the first low level signal by the detection result latching circuit and outputting a second low level signal; and receiving the second low level signal by the switch circuit and maintaining an off state of the switch circuit to cause the power loop to remain open.

In some embodiments, when the power loop remains open, the detection method further includes: generating a second pulse signal by the detection pulse generating module; receiving the second pulse signal through the detection result latching circuit by the switch circuit, and changing an off state of the switch circuit to a conducting state again during the second pulse signal to cause the power loop to be conducting once more; and detecting a second sampling signal on the power loop by the detection determining circuit as the power loop being conductive once more, and comparing the second sampling signal with the predefined signal, wherein when the second sampling signal is greater than or equal to the predefined signal, the detection method further includes: outputting the first high level signal by the detection determining circuit; receiving the first high level signal by the detection result latching circuit and outputting the second high level signal; and receiving the second high level signal by the switch circuit and maintaining a conducting state of the switch circuit to cause the power loop to remain conducting.

In some embodiments, when the second sampling signal is smaller than the predefined signal, the detection method further includes: outputting the first low level signal by the detection determining circuit; receiving the first low level signal by the detection result latching circuit and outputting the second low level signal; and receiving the second low level signal by the switch circuit and maintaining an off state of the switch circuit to cause the power loop to remain open.

In some embodiments, a period (or a width) of the first pulse signal is between 10 microseconds-1 millisecond, a period (or a width) of the second pulse signal is between 10 microseconds-1 millisecond.

In some embodiments, a time interval between the first and the second pulse signals (or a cycle of the pulse signal) includes $(X+Y)(T/2)$, where T is the cycle of the driving signal, X is an integer which is bigger than or equal to zero, $0<Y<1$.

In some embodiments, a period (or a width) of the first pulse signal is between 1 microsecond-100 microseconds, a period (or a width) of the second pulse signal is between 1 microsecond-100 microseconds.

In some embodiments, a time interval between the first and the second pulse signals (or a cycle of the pulse signal) is between 3 milliseconds-500 milliseconds.

In some embodiments, at least two protection elements, such as two fuses, are respectively connected between the internal circuits of the LED tube lamp and the conductive pins of the LED tube lamp, and which are on the power loop of the LED tube lamp. In some embodiments, four fuses are used for an LED tube lamp having power-supplied at its both end caps respectively having two conductive pins. In this case, for example, two fuses are respectively connected between two conductive pins of one end cap and between one of the two conductive pins of this end cap and the internal circuits of the LED tube lamp; and the other two fuses are respectively connected between two conductive pins of the other end cap and between one of the two conductive pins of the other end cap and the internal circuits of the LED tube lamp. In some embodiment, the capacitance between a power supply (or an external driving source) and the rectifying circuit of the LED tube lamp may be ranging from 0 to about 100 pF. In some embodiments, the above-mentioned installation detection module may be configured to use an external power supply.

According to the design of the power supply module, the external driving signal may be a low frequency AC signal (e.g., commercial power), a high frequency AC signal (e.g., that provided by an electronic ballast), or a DC signal (e.g., that provided by a battery or external configured driving source), input into the LED tube lamp through a drive architecture of dual-end power supply. For the drive architecture of dual-end power supply, the external driving signal may be input by using only one end thereof as single-end power supply.

The LED tube lamp may omit the rectifying circuit in the power supply module when the external driving signal is a DC signal.

According to the design of the rectifying circuit in the power supply module, there may be a dual rectifying circuit. First and second rectifying circuits of the dual rectifying circuit are respectively coupled to the two end caps disposed on two ends of the LED tube lamp. The dual rectifying circuit is applicable to the drive architecture of dual-end power supply. Furthermore, the LED tube lamp having at least one rectifying circuit is applicable to the drive architecture of a low frequency AC signal, high frequency AC signal or DC signal.

The dual rectifying circuit may comprise, for example, two half-wave rectifier circuits, two full-wave bridge rectifying circuits or one half-wave rectifier circuit and one full-wave bridge rectifying circuit.

According to the design of the pin in the LED tube lamp, there may be two pins in single end (the other end has no pin), two pins in corresponding ends of two ends, or four pins in corresponding ends of two ends. The designs of two pins in single end and two pins in corresponding ends of two ends are applicable to a signal rectifying circuit design of the rectifying circuit. The design of four pins in corresponding ends of two ends is applicable to a dual rectifying circuit design of the rectifying circuit, and the external driving signal can be received by two pins in only one end or any pin in each of two ends.

According to the design of the filtering circuit of the power supply module, there may be a single capacitor, or π filter circuit. The filtering circuit filers the high frequency component of the rectified signal for providing a DC signal with a low ripple voltage as the filtered signal. The filtering circuit also further comprises the LC filtering circuit having a high impedance for a specific frequency for conforming to current limitations in specific frequencies of the UL standard. Moreover, the filtering circuit according to some embodiments further comprises a filtering unit coupled between a rectifying circuit and the pin(s) for reducing the EMI resulted from the circuit(s) of the LED tube lamp. The LED tube lamp may omit the filtering circuit in the power supply module when the external driving signal is a DC signal.

According to the design of the LED lighting module in some embodiments, the LED lighting module may comprise the LED module and the driving circuit or only the LED module. The LED module may be connected with a voltage stabilization circuit in parallel for preventing the LED module from over voltage. The voltage stabilization circuit may be a voltage clamping circuit, such as Zener diode, DIAC and so on. When the rectifying circuit has a capacitive circuit, in some embodiments, two capacitors are respectively coupled between two corresponding pins in two end caps and so the two capacitors and the capacitive circuit as a voltage stabilization circuit perform a capacitive voltage divider.

If there are only the LED module in the LED lighting module and the external driving signal is a high frequency AC signal, a capacitive circuit (e.g., having at least one capacitor) is in at least one rectifying circuit and the capacitive circuit is connected in series with a half-wave rectifier circuit or a full-wave bridge rectifying circuit of the rectifying circuit and serves as a current modulation circuit (or a current regulator) to modulate or to regulate the current of the LED module due to that the capacitor equates a resistor for a high frequency signal. Thereby, even different ballasts provide high frequency signals with different voltage logic levels, the current of the LED module can be modulated into a defined current range for preventing overcurrent. In addition, an energy-releasing circuit is connected in parallel with the LED module. When the external driving signal is no longer supplied, the energy-releasing circuit releases the energy stored in the filtering circuit to lower a resonance effect of the filtering circuit and other circuits for restraining the flicker of the LED module. In some embodiments, if there are the LED module and the driving circuit in the LED lighting module, the driving circuit may be a buck converter, a boost converter, or a buck-boost converter. The driving circuit stabilizes the current of the LED module at a defined current value, and the defined current value may be modulated based on the external driving signal. For example, the defined current value may be increased with the increasing of the logic level of the external driving signal and reduced with the reducing of the logic level of the external driving signal. Moreover, a mode switching circuit may be added between the LED module and the driving circuit for switching the current from the filtering circuit directly or through the driving circuit inputting into the LED module.

A protection circuit may be additionally added to protect the LED module. The protection circuit detects the current and/or the voltage of the LED module to determine whether to enable corresponding over current and/or over voltage protection.

According to the design of the auxiliary power module of the power supply module, the energy storage unit may be a battery or a supercapacitor, connected in parallel with the LED module. The auxiliary power module is applicable to the LED lighting module having the driving circuit.

According to the design of the LED module of the power supply module, the LED module comprises plural strings of LEDs connected in parallel with each other, wherein each LED may have a single LED chip or plural LED chips emitting different spectrums. Each LEDs in different LED strings may be connected with each other to form a mesh connection.

In other words, the abovementioned features can be implemented in any combination to improve the LED tube lamp.

The above-mentioned exemplary features of the present invention can be accomplished in any combination to improve the LED tube lamp, and the above embodiments are described by way of example only. The present invention is not herein limited, and many variations are possible without departing from the spirit of the present invention and the scope as defined in the appended claims.

What is claimed is:

1. An installation detection circuit configured in a light-emitting diode (LED) tube lamp configured to receive an external driving signal, the installation detection circuit comprising:

a pulse generating circuit configured to output one or more pulse signals; wherein the installation detection circuit is configured to detect during at least one of the one or more pulse signals whether the LED tube lamp is properly installed on a lamp socket, based on detecting a signal generated from the external driving signal; and

a switch circuit coupled to the pulse generating circuit, wherein the one or more pulse signals control turning on and off of the switch circuit;

wherein the installation detection circuit is further configured to:

when it is detected during one of the one or more pulse signals that the LED tube lamp is not properly installed on the lamp socket, control the switch circuit to remain in an off state to cause a power loop of the LED tube lamp to be open; and

when it is detected during one of the one or more pulse signals that the LED tube lamp is properly installed on the lamp socket, control the switch circuit to remain in a conducting state to cause the power loop of the LED tube lamp to maintain a conducting state,

wherein the signal generated from the external driving signal is a sampling signal on the power loop, the installation detection circuit further comprises a detection determining circuit configured to detect the sampling signal for determining whether the LED tube lamp is properly installed on the lamp socket, and the power loop includes the switch circuit and the detection determining circuit, and

wherein the pulse generating circuit is configured to output one or more pulse signals independent of whether the detection determining circuit detects the sampling signal.

2. The installation detection circuit according to claim **1**, wherein the pulse generating circuit comprises:

a first capacitor, one end connected to a driving signal;

a first resistor, one end connected to the other end of the first capacitor, the other end the first resistor connected to a reference voltage;

a first buffer, having an input end and an output end, the input end connected to the other end of the first capacitor;

a second capacitor, one end connected to the output end of the first buffer;

a third capacitor, one end connected to the output end of the first buffer;

a second resistor, one end connected to the driving signal, the other end of the second resistor connected to the other end of the second capacitor;

a third resistor, one end connected to the other end of the third capacitor, the other end of the third resistor connected to a reference voltage;

a first diode, having an anode and a cathode, the anode connected to the other end of the third resistor, the cathode connected to the one end of the third resistor that is not connected to a reference voltage;

a first inverter, having an input end and an output end, the input end connected to the other end of the second capacitor;

a second buffer, having an input end and an output end, the input end connected to the other end of the third capacitor; and

a first OR gate, having a first input end, a second input end, and an output end, the first input end connected to the output end of the first inverter, the second input end connected to the output end of the second buffer, the output end of the first OR gate for outputting the one or more pulse signals.

3. The installation detection circuit according to claim **1**, wherein when the detection determining circuit determines that the sampling signal is greater than or equal to a predefined signal, it is detected that the LED tube lamp is properly installed on the lamp socket; and when the detection determining circuit determines that the sampling signal is smaller than a predefined signal, it is detected that the LED tube lamp is not properly installed on the lamp socket.

4. An installation detection circuit configured in a light-emitting diode (LED) tube lamp configured to receive an external driving signal, the installation detection circuit comprising:

a pulse generating circuit configured to output one or more pulse signals; wherein the installation detection circuit is configured to detect during at least one of the one or more pulse signals whether the LED tube lamp is properly installed on a lamp socket, based on detecting a signal generated from the external driving signal; and

a switch circuit coupled to the pulse generating circuit, wherein the one or more pulse signals control turning on and off of the switch circuit;

wherein the installation detection circuit is further configured to:

when it is detected during one of the one or more pulse signals that the LED tube lamp is not properly installed on the lamp socket, control the switch circuit to remain in an off state to cause a power loop of the LED tube lamp to be open; and

when it is detected during one of the one or more pulse signals that the LED tube lamp is properly installed on the lamp socket, control the switch circuit to remain in a conducting state to cause the power loop of the LED tube lamp to maintain a conducting state, and

wherein the signal generated from the external driving signal is a sampling signal on the power loop, the installation detection circuit further comprises a detection determining circuit configured to detect the sampling signal for determining whether the LED tube lamp is properly installed on the lamp socket, and the power loop includes the switch circuit and the detection determining circuit; and

wherein the installation detection circuit further includes a detection result latching circuit coupled to the switch circuit, wherein the detection result latching circuit is configured to receive the one or more pulse signals to control turning on and off of the switch circuit based on a detection result signal from the detection determining circuit.

5. The installation detection circuit according to claim **4**, wherein the pulse generating circuit is coupled to an output of the detection result latching circuit to control the time of the one or more pulse signals.

6. The installation detection circuit according to claim **4**, wherein the pulse generating circuit comprises:

a second capacitor, one end coupled to a driving signal;

a third capacitor, one end coupled to the driving signal;

a second resistor, one end connected to the driving signal, the other end of the second resistor connected to the other end of the second capacitor;

a third resistor, one end connected to the other end of the third capacitor, the other end of the third resistor connected to a reference voltage;

a first diode, having an anode and a cathode, the anode connected to the other end of the third resistor, the cathode connected to the one end of the third resistor that is not connected to a reference voltage;

a first inverter, having an input end and an output end, the input end connected to the other end of the second capacitor;

a second buffer, having an input end and an output end, the input end connected to the other end of the third capacitor; and

a first OR gate, having a first input end, a second input end, and an output end, the first input end connected to the output end of the first inverter, the second input end connected to the output end of the second buffer, the output end of the first OR gate for outputting the one or more pulse signals.

7. The installation detection circuit according to claim **6**, wherein the second buffer comprises two inverters connected in series.

8. The installation detection circuit according to claim **6**, wherein the detection result latching circuit comprises:

a first D flip-flop, having a data input end, a clock input end, and an output end, the data input end connected to the driving signal, the clock input end connected to the detection determining circuit;

a fourth resistor, one end connected to the output end of the first D flip-flop, the other end of the fourth resistor connected to a reference voltage; and

a second OR gate, having a first input end, a second input end, and an output end, the first input end connected to the output end of the first OR gate, the second input end connected to the output end of the first D flip-flop, the output end of the second OR gate connected to the switch circuit.

9. The installation detection circuit according to claim **6**, wherein the switch circuit comprises:

a first transistor, having a base, a collector, and an emitter, the base connected to the detection result latching circuit, the collector connected to one end of the power loop, the emitter connected to the detection determining circuit.

10. The installation detection circuit according to claim **6**, wherein the detection determining circuit comprises:

a fifth resistor, one end connected to the switch circuit, the other end of the fifth resistor connected to a second end of the power loop; and

a first comparator, having a first input end, a second input end, and an output end, the first input end connected to a predefined signal, the second input end connected to the one end of the fifth resistor, the output end of the first comparator connected to the detection result latching circuit.

11. The installation detection circuit according to claim **4**, wherein the pulse generating circuit comprises:

a sixth resistor, one end connected to a driving signal;

a fourth capacitor, one end connected to the other end of the sixth resistor, the other end of the fourth capacitor connected to a reference voltage;

a Schmitt trigger, having an input end and an output end, the input end connected to the one end of the fourth capacitor, the output end connected to the detection result latching circuit;

a seventh resistor, one end connected to the one end of the fourth capacitor;

a second transistor, having a base, a collector, and an emitter, the collector connected to the other end of the seventh resistor, the emitter connected to a reference voltage; and

an eighth resistor, one end connected to the base of the second transistor, the other end of the eighth resistor connected to the detection result latching circuit and the switch circuit.

12. The installation detection circuit according to claim **11**, wherein the pulse generating circuit further comprises:

a Zener diode, having an anode and a cathode, the anode connected to the other end of the fourth capacitor, the cathode connected to the one end of the fourth capacitor.

13. The installation detection circuit according to claim **11**, wherein the detection result latching circuit comprises:

a second D flip-flop, having a data input end, a clock input end, and an output end, the data input end connected to the driving signal, the clock input end connected to the detection determining circuit; and

a third OR gate, having a first input end, a second input end, and an output end, the first input end connected to the output end of the Schmitt trigger, the second input end connected to the output end of the second D flip-flop, the output end of the third OR gate connected to the other end of the eighth resistor and the switch circuit.

14. The installation detection circuit according to claim **11**, wherein the switch circuit comprises:

a third transistor, having a base, a collector, and an emitter, the base connected to the detection result latching circuit, the collector connected to one end of the power loop, the emitter connected to the detection determining circuit.

15. The installation detection circuit according to claim **11**, wherein the detection determining circuit comprises:

a ninth resistor, one end connected to the switch circuit, the other end of the ninth resistor connected to a second end of the power loop; and

a second comparator, having a first input end, a second input end, and an output end, the first input end connected to a predefined signal, the second input end connected to the one end of the ninth resistor, the output end of the second comparator connected to the detection result latching circuit.

16. The installation detection circuit according to claim **11**, wherein the detection determining circuit comprises:

a ninth resistor, one end connected to the switch circuit, the other end of the ninth resistor connected to a second end of the power loop;

a second diode, having an anode and a cathode, the anode connected to the one end of the ninth resistor;

a second comparator, having a first input end, a second input end, and an output end, the first input end connected to a predefined signal, the second input end connected to the cathode of the second diode, the output end of the second comparator connected to the detection result latching circuit;

a third comparator, having a first input end, a second input end, and an output end, the first input end connected to the cathode of the second diode, the second input end connected to another predefined signal, the output end of the third comparator connected to the detection result latching circuit;

a tenth resistor, one end connected to the driving signal;

an eleventh resistor, one end connected to the other end of the tenth resistor and the second input end of the second comparator, the other end of the eleventh resistor connected to a reference voltage; and

a fifth capacitor, connected to the eleventh resistor in parallel.

17. An installation detection circuit configured in a light-emitting diode (LED) tube lamp configured to receive an external driving signal, the installation detection circuit comprising:

a pulse generating circuit configured to output one or more pulse signals; wherein the installation detection circuit is configured to detect during at least one of the one or more pulse signals whether the LED tube lamp is properly installed on a lamp socket, based on detecting a signal generated from the external driving signal; and

a switch circuit coupled to the pulse generating circuit, wherein the one or more pulse signals control turning on and off of the switch circuit;

wherein the installation detection circuit is further configured to:

when it is detected during one of the one or more pulse signals that the LED tube lamp is not properly installed on the lamp socket, control the switch circuit to remain in an off state to cause a power loop of the LED tube lamp to be open; and

when it is detected during one of the one or more pulse signals that the LED tube lamp is properly installed on the lamp socket, control the switch circuit to remain in a conducting state to cause the power loop of the LED tube lamp to maintain a conducting state, and

wherein the LED tube lamp comprises a lamp tube and a circuit board, and comprises an inductive element connected between two terminals respectively at two ends of the lamp tube for grounding or connecting to a reference potential, wherein one of the two terminals is connected to the circuit board.

18. The installation detection circuit according to claim **17**, wherein the inductive element is an inductor.

19. The installation detection circuit according to claim **18**, wherein one end of the inductor is directly electrically connected to the circuit board.

20. The installation detection circuit according to claim **1**, wherein a period of each of the one or more pulse signals is between 1 microsecond and 1 millisecond.

21. An installation detection circuit configured in a light-emitting diode (LED) tube lamp, the installation detection circuit comprising:

means for generating one or more pulse signals;

means for detecting during one or more pulse signals whether the LED tube lamp is properly installed on a lamp socket; and

a switch circuit coupled to the means for generating one or more pulse signals, wherein the one or more pulse signals control turning on and off of the switch circuit;

wherein the installation detection circuit is further configured to:

when it is detected during one of the one or more pulse signals that the LED tube lamp is not properly installed on the lamp socket, control the switch circuit to remain in an off state to cause a power loop of the LED tube lamp to be open; and

when it is detected during one of the one or more pulse signals that the LED tube lamp is properly installed on the lamp socket, control the switch circuit to remain in a conducting state to cause the power loop of the LED tube lamp to maintain a conducting state,

wherein the means for detecting is configured to detect a sampling signal on the power loop for determining whether the LED tube lamp is properly installed on the lamp socket, and the power loop includes the switch circuit and the means for detecting, and

wherein the LED tube lamp is configured to receive an external driving signal and comprises a rectifying circuit for rectifying the external driving signal and a filtering circuit coupled to the rectifying circuit, wherein the installation detection circuit is coupled between the rectifying circuit and the filtering circuit.

22. The installation detection circuit according to claim **21**, wherein when the means for detecting determines that the sampling signal is greater than or equal to a predefined signal, it is detected that the LED tube lamp is properly installed on the lamp socket; and when the means for detecting determines that the sampling signal is smaller than a predefined signal, it is detected that the LED tube lamp is not properly installed on the lamp socket.

23. The installation detection circuit according to claim **21**, further comprising a detection result latching circuit coupled to the switch circuit, wherein the detection result latching circuit is configured to receive the one or more pulse signals to control turning on and off of the switch circuit based on a detection result signal from the means for detecting.

24. A detection method adopted by a light-emitting device (LED) tube lamp for preventing a user from electric shock when the LED tube lamp is being installed on a lamp socket, the detection method comprising:

when at least one end of the LED tube lamp is installed on the lamp socket, generating one or more pulse signals by a pulse generating circuit, wherein the pulse generating circuit is configured in the LED tube lamp;

detecting a sampling signal on a power loop of the LED tube lamp by a detection determining circuit, to detect during the one or more pulse signals whether the other end of the LED tube lamp is properly installed on the lamp socket;

receiving the one or more pulse signals through a detection result latching circuit by a switch circuit, wherein the switch circuit is on the power loop; and

comparing the sampling signal with a predefined signal, wherein during the one or more pulse signals when the sampling signal is smaller than the predefined signal, the detection method further comprises:

controlling the switch circuit to remain in an off state to cause the power loop of the LED tube lamp to be open.

25. The detection method according to claim **24**, wherein the step of controlling the switch circuit to remain in an off state to cause the power loop of the LED tube lamp to be open comprises:

outputting a first low level signal by the detection determining circuit;

receiving the first low level signal by the detection result latching circuit and outputting a second low level signal; and

receiving the second low level signal by the switch circuit and maintaining an off state of the switch circuit to cause the power loop to be open.

26. The detection method according to claim **24**, wherein during any of the one or more pulse signals when the sampling signal is greater than or equal to the predefined signal, the detection method further comprises:

controlling the switch circuit to remain in a conducting state to cause the power loop of the LED tube lamp to maintain a conducting state.

27. The detection method according to claim **26**, wherein the step of controlling the switch circuit to remain in a conducting state to cause the power loop of the LED tube lamp to maintain a conducting state comprises:

outputting a first high level signal by the detection determining circuit;

receiving the first high level signal by the detection result latching circuit and outputting a second high level signal; and

receiving the second high level signal by the switch circuit and conducting the switch circuit to cause the power loop to maintain a conducting state.

28. The detection method according to claim **24**, wherein a period of each of the one or more pulse signals is between 10 microseconds and 1 millisecond.

29. The detection method according to claim **24**, wherein a period of each of the one or more pulse signals is between 1 microsecond and 100 microseconds.

30. The installation detection circuit according to claim **4**, configured such that when the detection determining circuit determines that the sampling signal is greater than or equal to a predefined signal, it is detected that the LED tube lamp is properly installed on the lamp socket; and when the detection determining circuit determines that the sampling signal is smaller than a predefined signal, it is detected that the LED tube lamp is not properly installed on the lamp socket.

31. The installation detection circuit according to claim **1**, further comprising a detection result latching circuit coupled to the switch circuit, wherein the detection result latching circuit is configured to receive the one or more pulse signals to control turning on and off of the switch circuit based on a detection result signal from the detection determining circuit.

32. The installation detection circuit according to claim **31**, wherein the pulse generating circuit is coupled to an output of the detection result latching circuit to control the time of the one or more pulse signals.

33. The installation detection circuit according to claim **31**, wherein the pulse generating circuit comprises:

a second capacitor, one end coupled to a driving signal;

a third capacitor, one end coupled to the driving signal;

a second resistor, one end connected to the driving signal, the other end of the second resistor connected to the other end of the second capacitor;

a third resistor, one end connected to the other end of the third capacitor, the other end of the third resistor connected to a reference voltage;

a first diode, having an anode and a cathode, the anode connected to the other end of the third resistor, the cathode connected to the one end of the third resistor that is not connected to a reference voltage;

a first inverter, having an input end and an output end, the input end connected to the other end of the second capacitor;

a second buffer, having an input end and an output end, the input end connected to the other end of the third capacitor; and

a first OR gate, having a first input end, a second input end, and an output end, the first input end connected to the output end of the first inverter, the second input end connected to the output end of the second buffer, the output end of the first OR gate for outputting the one or more pulse signals.

34. The installation detection circuit according to claim **31**, wherein the pulse generating circuit comprises:

a sixth resistor, one end connected to a driving signal;

a fourth capacitor, one end connected to the other end of the sixth resistor, the other end of the fourth capacitor connected to a reference voltage;

a Schmitt trigger, having an input end and an output end, the input end connected to the one end of the fourth capacitor, the output end connected to the detection result latching circuit;

a seventh resistor, one end connected to the one end of the fourth capacitor;

a second transistor, having a base, a collector, and an emitter, the collector connected to the other end of the seventh resistor, the emitter connected to a reference voltage; and

an eighth resistor, one end connected to the base of the second transistor, the other end of the eighth resistor connected to the detection result latching circuit and the switch circuit.

35. The installation detection circuit according to claim **1**, wherein a period of each of the one or more pulse signals is between 1 microsecond and 1 millisecond.

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(54) **LED TUBE LAMP**

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(Continued)

(58) **Field of Classification Search**
None
See application file for complete search history.

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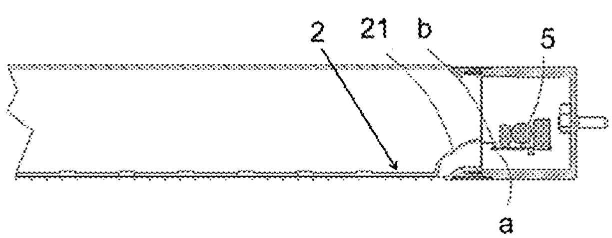
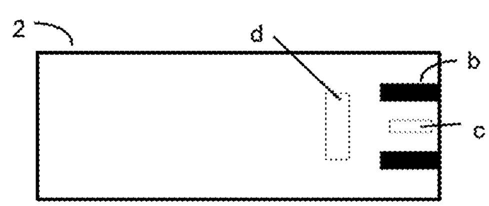
Primary Examiner — Anh Q Tran
(74) *Attorney, Agent, or Firm* — Andrew M. Calderon; Roberts Mlotkowski Safran Cole & Calderon, P.C.

(57) **ABSTRACT**

An LED tube lamp comprises a lamp tube, two end caps attached at two ends of the lamp tube respectively, a power supply disposed in one of the two end caps or separately in both of the end caps, an LED light strip disposed inside the lamp tube and a protective layer disposed on the LED light strip. The LED light strip comprises a mounting region and a connecting region. The plurality of LED light sources is mounted on the mounting region and two soldering pads are disposed on the connecting region. The mounting region and the connecting region are electrically connecting the plurality of LED light sources with the power supply. The protective layer comprises a plurality of first openings arranged on the mounting region for accommodating the LED light sources and two second openings are arranged on the connecting region for accommodating the two soldering pad.

54 Claims, 43 Drawing Sheets





Related U.S. Application Data

continuation of application No. 14/865,387, filed on Sep. 25, 2015, now Pat. No. 9,609,711.

(30) **Foreign Application Priority Data**

Nov. 6, 2014	(CN)	201410623355
Dec. 5, 2014	(CN)	201410734425
Feb. 12, 2015	(CN)	201510075925
Mar. 10, 2015	(CN)	201510104823
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(51) **Int. Cl.**

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F21K 9/272	(2016.01)
F21V 3/06	(2018.01)
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(52) **U.S. Cl.**

CPC ***F21K 9/235*** (2016.08); ***F21K 9/27*** (2016.08); ***F21K 9/275*** (2016.08); ***F21K 9/278*** (2016.08); ***F21V 3/061*** (2018.02); ***F21V 3/10*** (2018.02); ***F21V 7/22*** (2013.01); ***F21V 15/015*** (2013.01); ***F21V 17/101*** (2013.01); ***F21V 23/009*** (2013.01); ***F21V 23/02*** (2013.01); ***F21V 25/02*** (2013.01); ***F21V 29/83*** (2015.01); ***H05B 6/105*** (2013.01); ***H05B 33/0803*** (2013.01); ***H05B 33/0809*** (2013.01); ***H05B 33/0815*** (2013.01); ***H05B 33/0845*** (2013.01); ***H05B 33/0884*** (2013.01); *B23K 2101/42* (2018.08); *C03C 21/002* (2013.01); *C03C 27/048* (2013.01); *F21K 9/68* (2016.08); *F21V 25/04* (2013.01); *F21V 29/70* (2015.01); *F21Y 2101/00* (2013.01); *F21Y 2103/00* (2013.01); *F21Y 2103/10* (2016.08); *F21Y 2115/10* (2016.08); *H05B 33/089* (2013.01)

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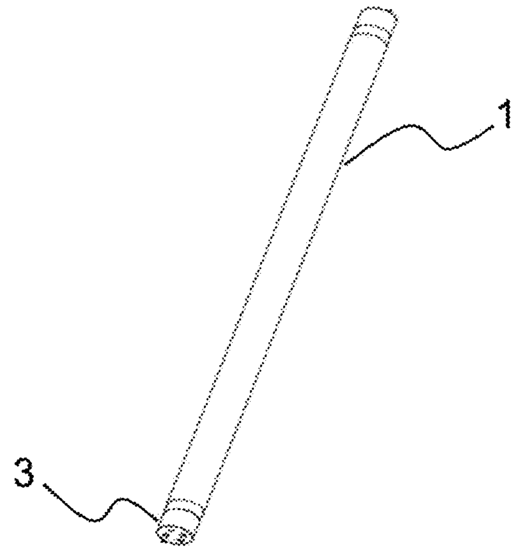

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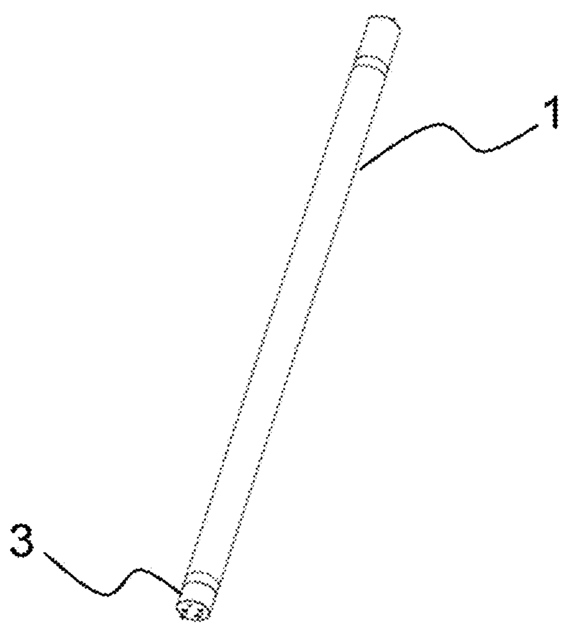


Fig. 1A

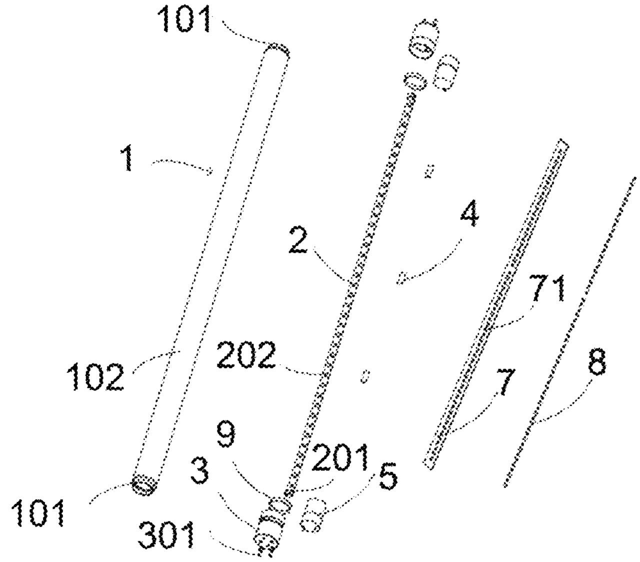


Fig. 2

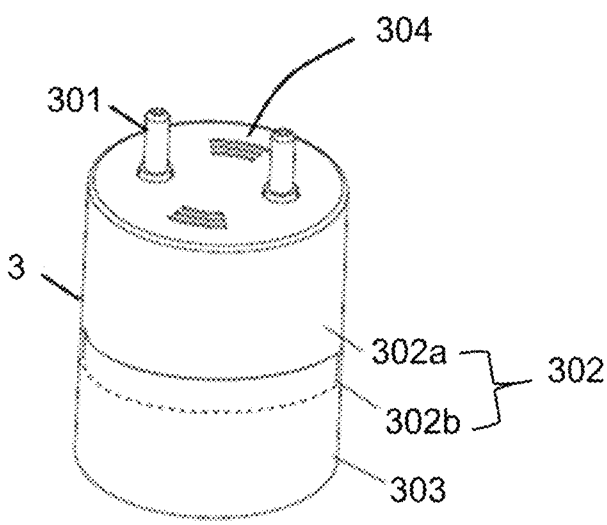


Fig. 3

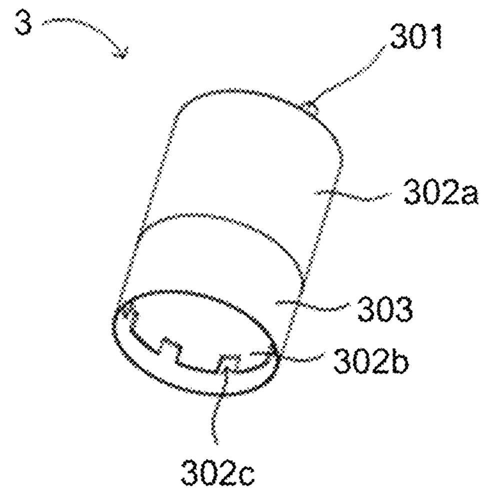


Fig. 4

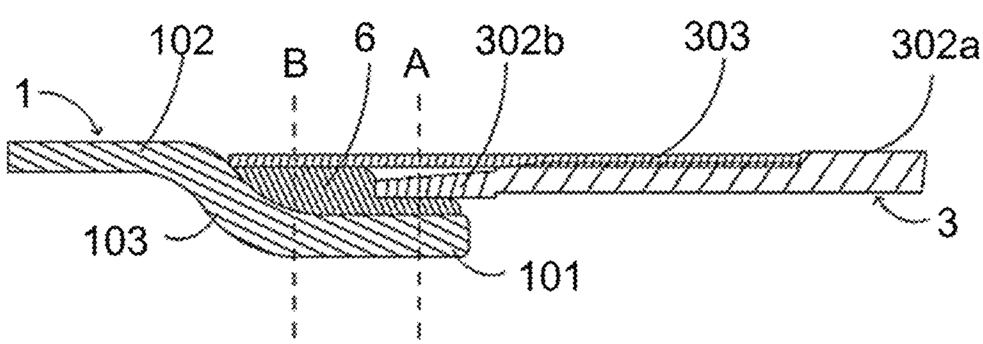
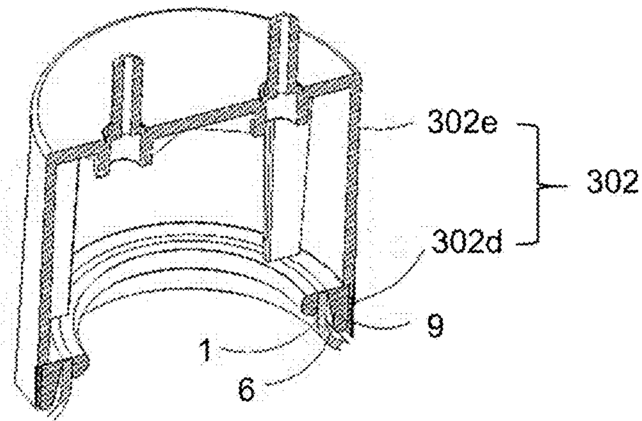


Fig. 5



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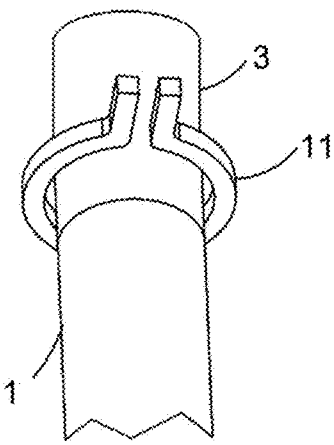

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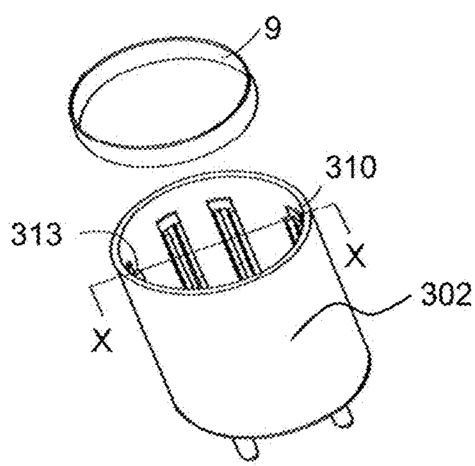

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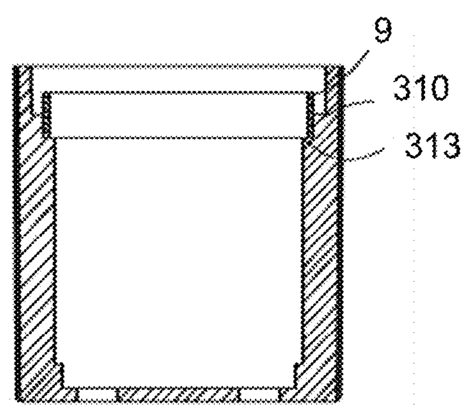

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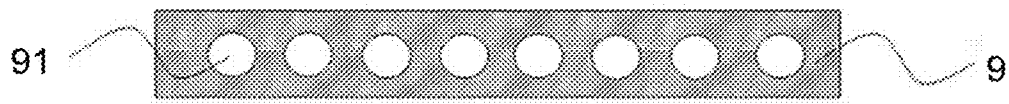


Fig. 10

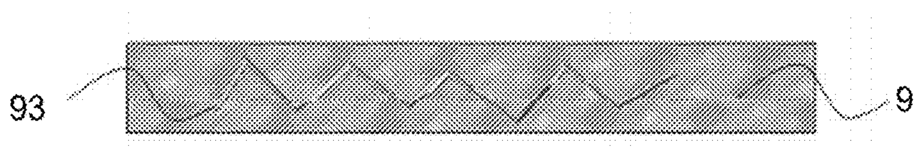


Fig. 11

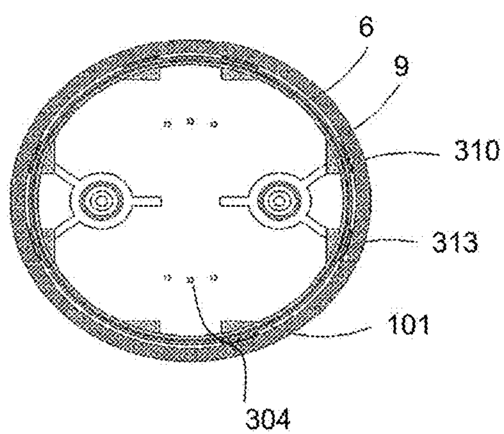


Fig. 12

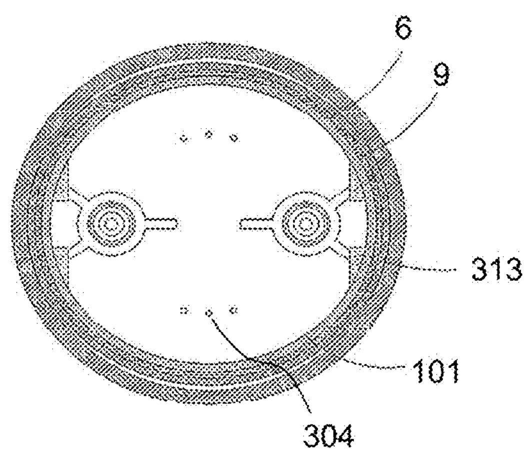
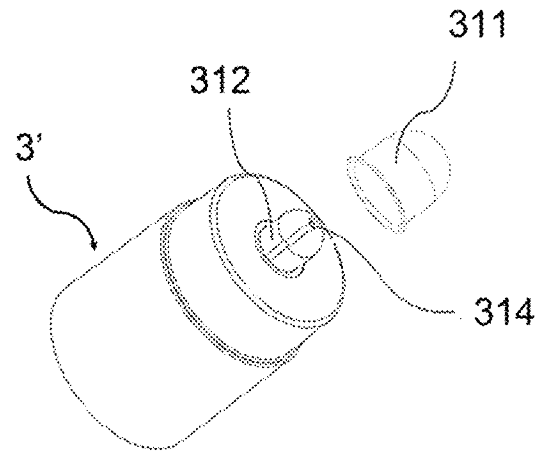


Fig. 13



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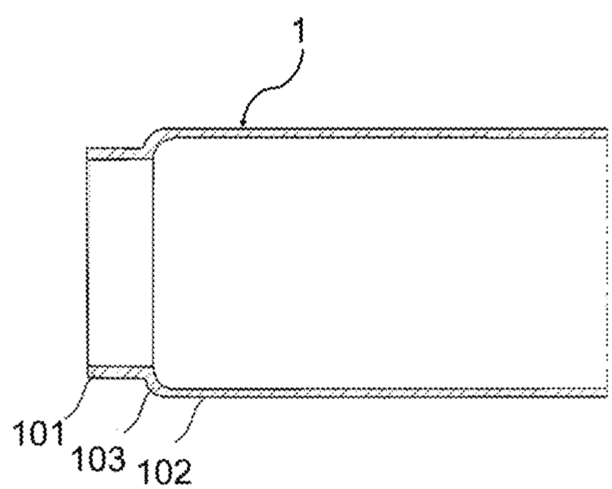

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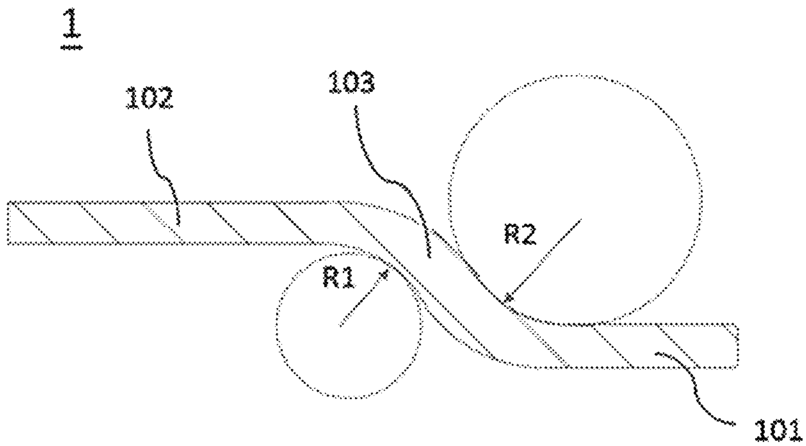


Fig. 16

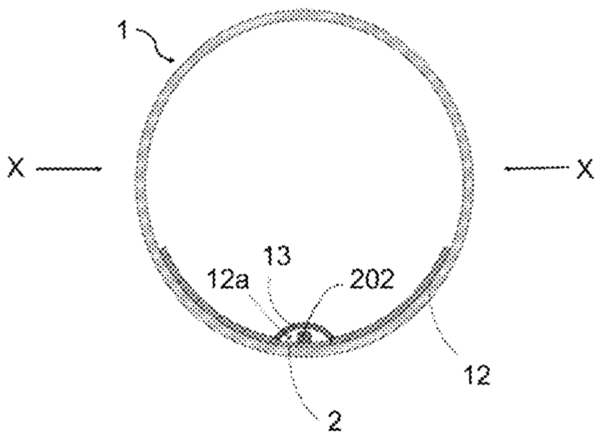


Fig. 17

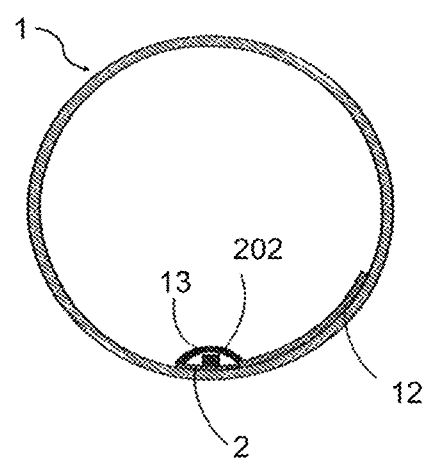


Fig. 18

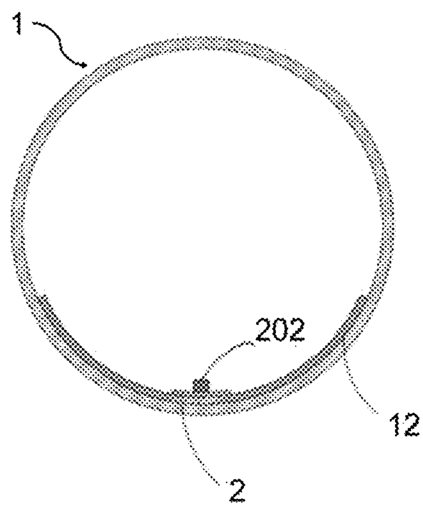


Fig. 19

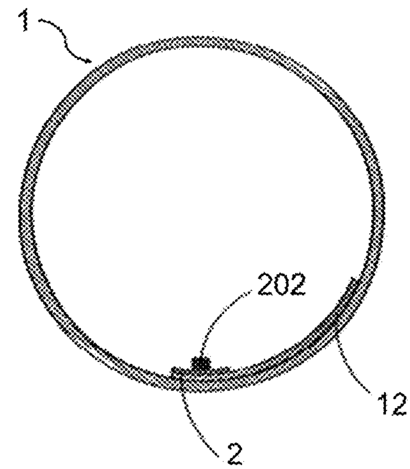


Fig. 20

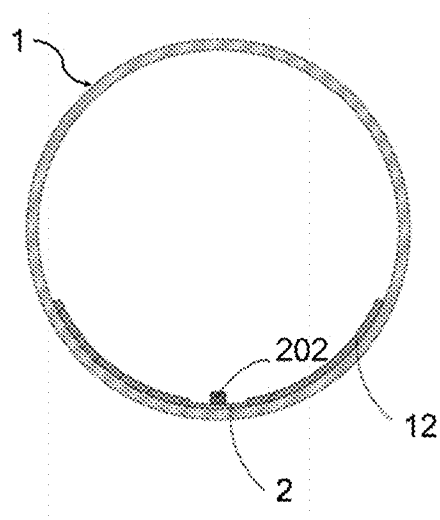


Fig. 21

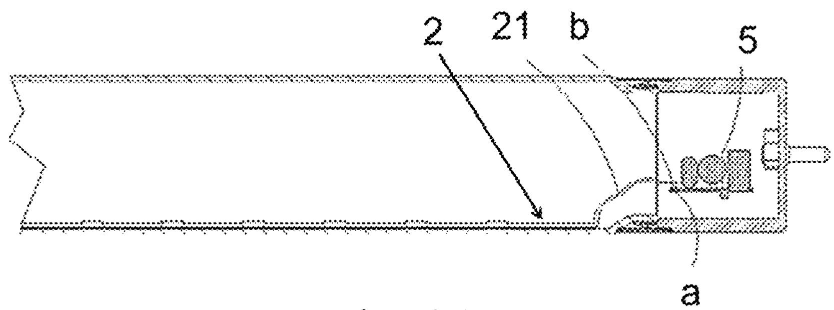


Fig. 22

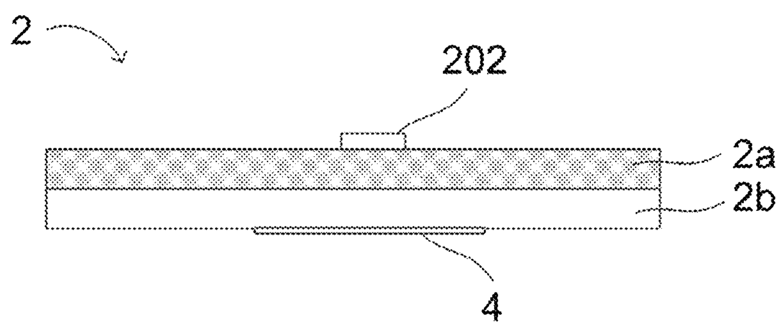
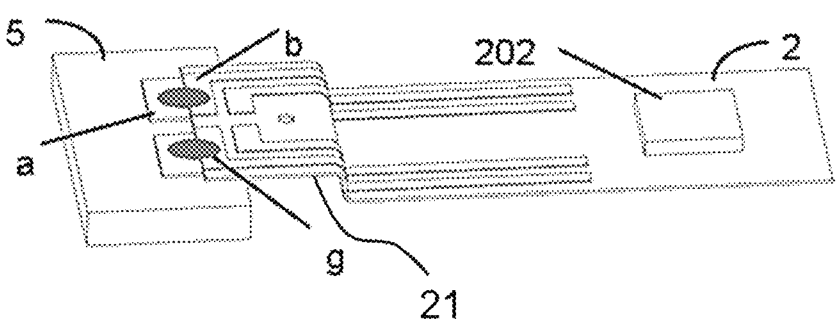


Fig. 23



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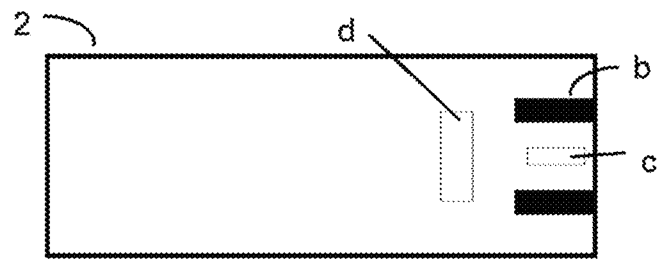


Fig. 25

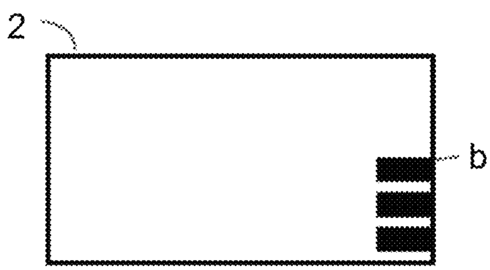


Fig. 26

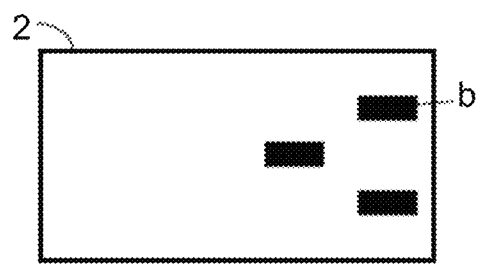


Fig. 27

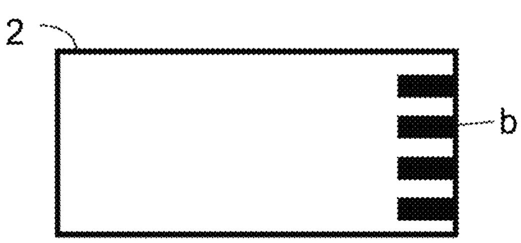


Fig. 28

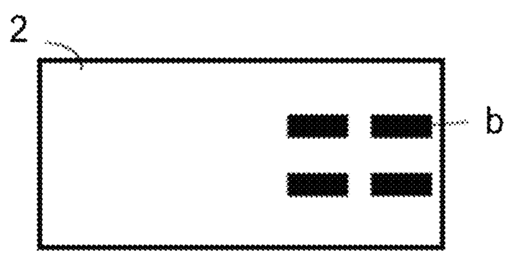


Fig. 29

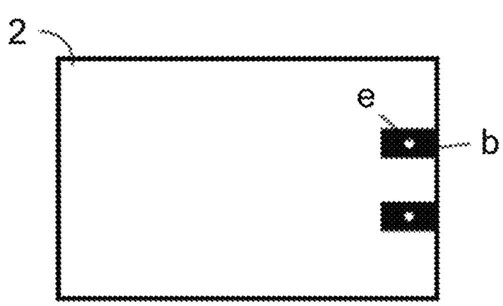


Fig. 30

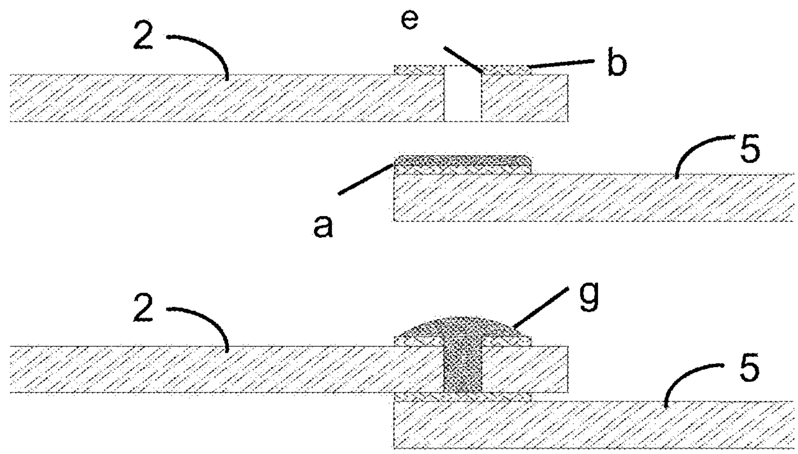


Fig. 31

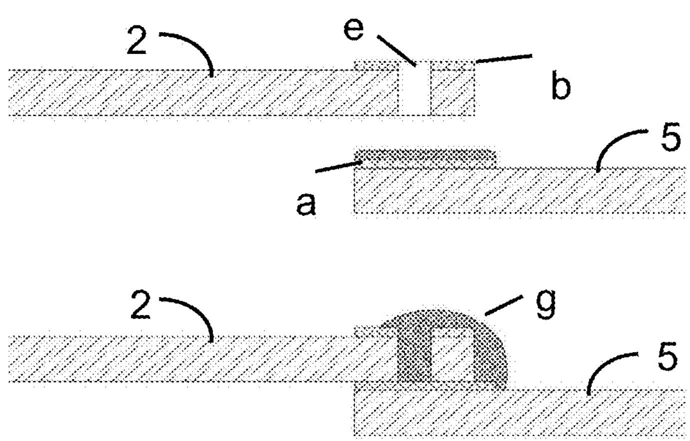
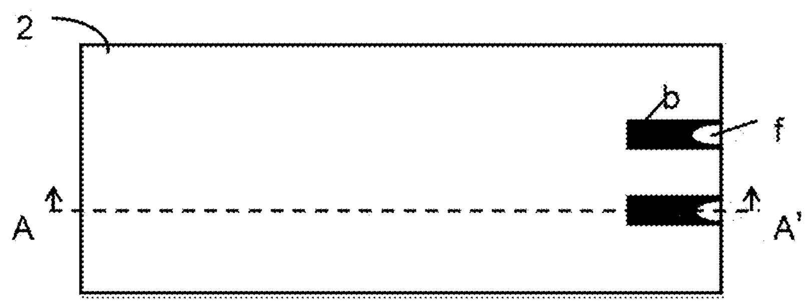


Fig. 32



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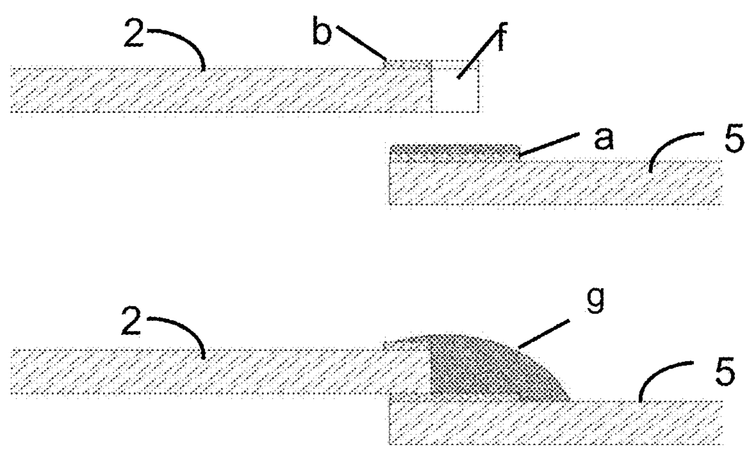

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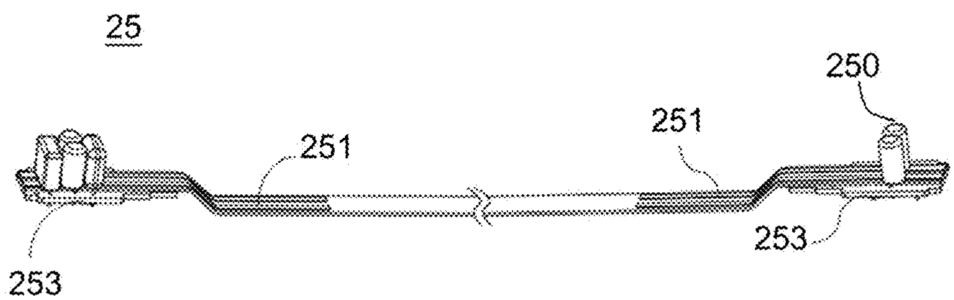

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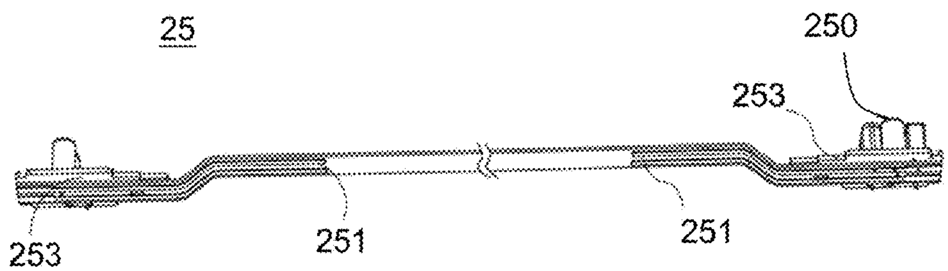

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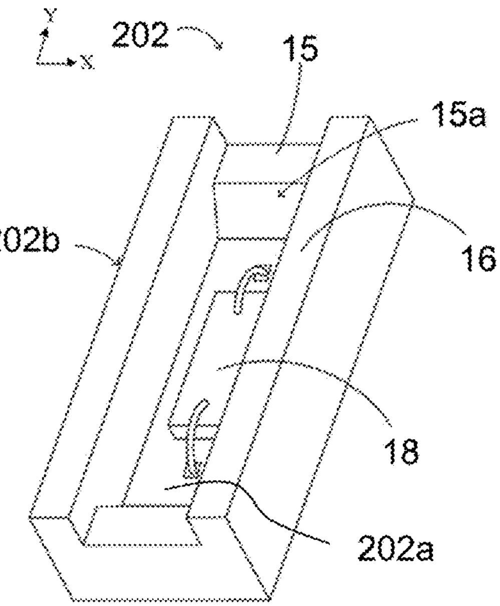


Fig. 37

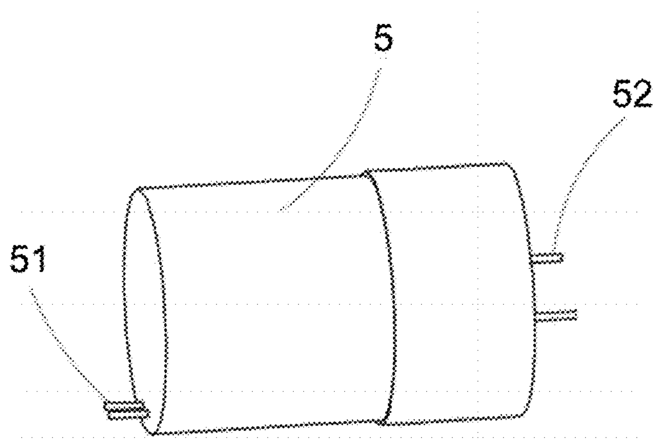


Fig. 38

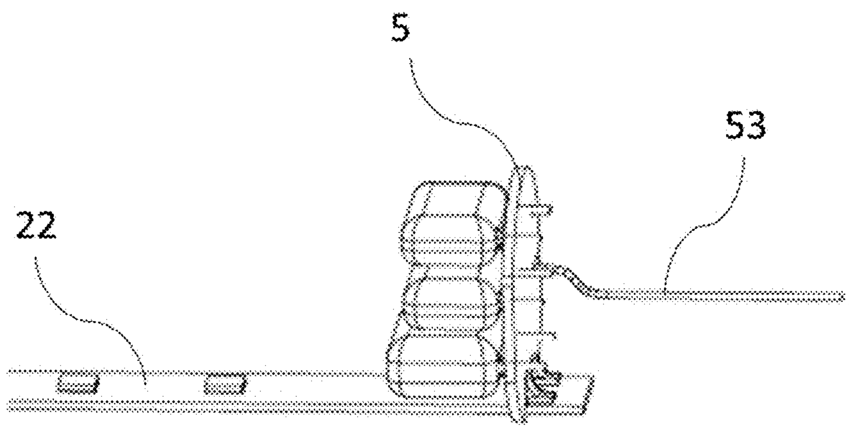


Fig. 39

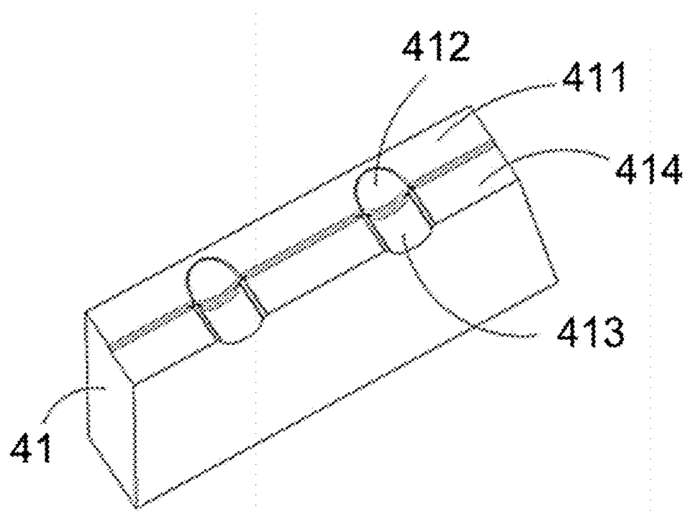


Fig. 40

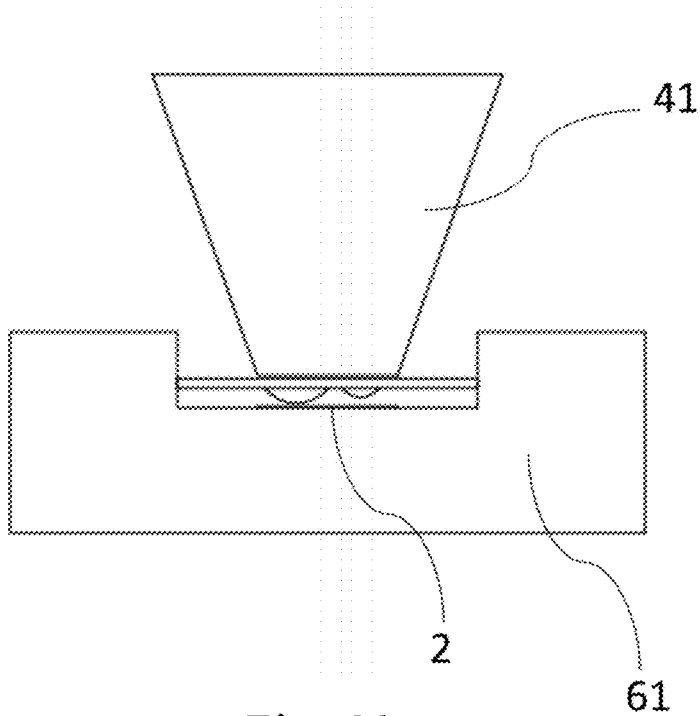


Fig. 41

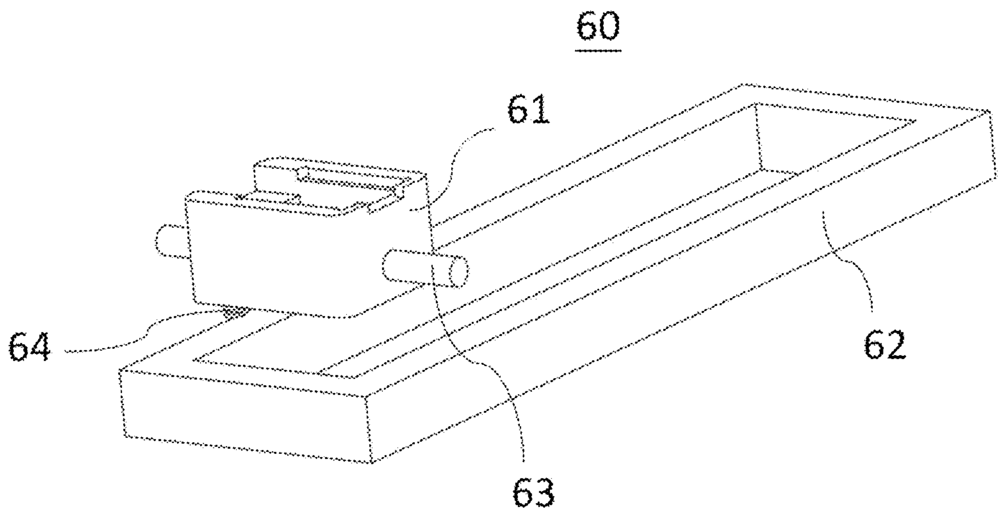


Fig. 42

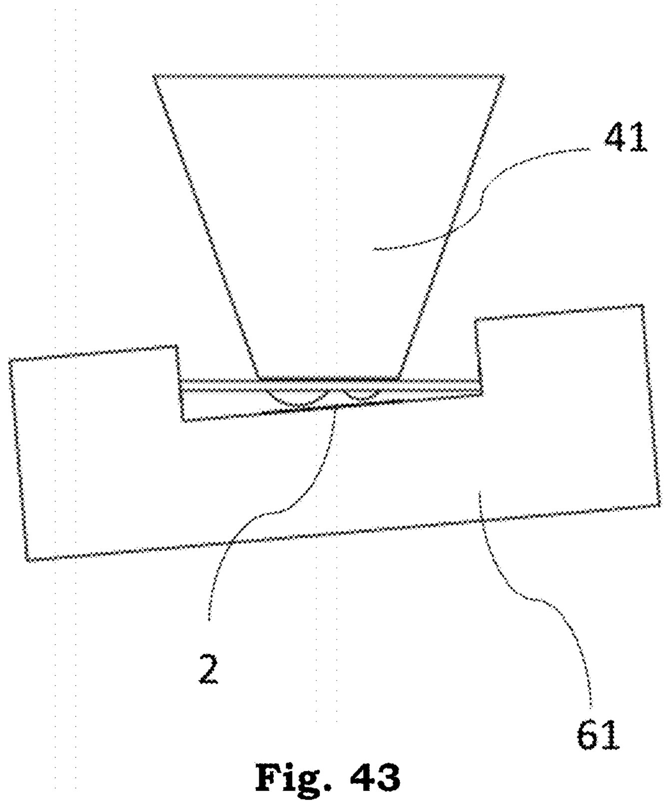


Fig. 43

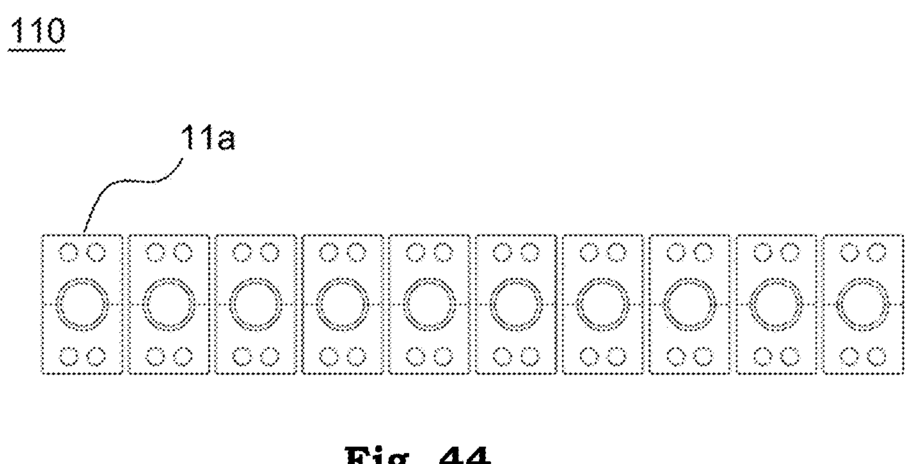
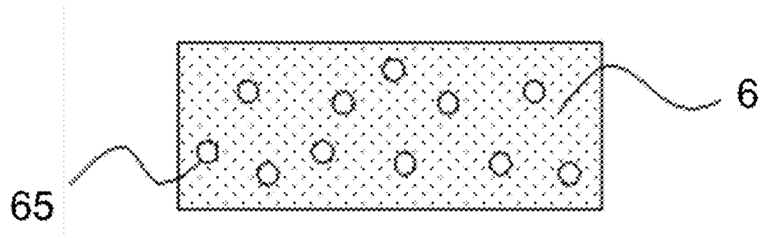


Fig. 44



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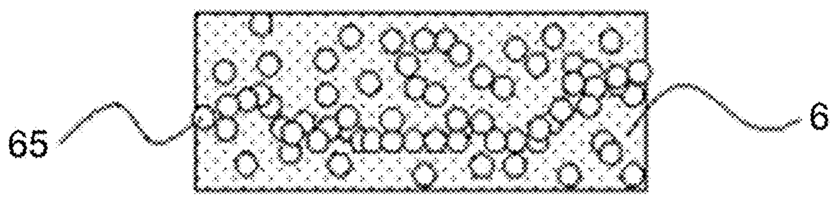

Fig. 46

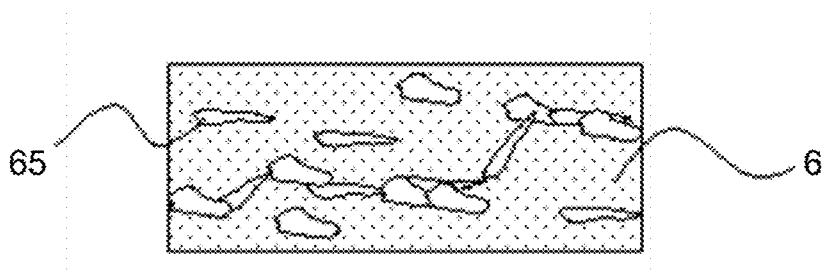

Fig. 47

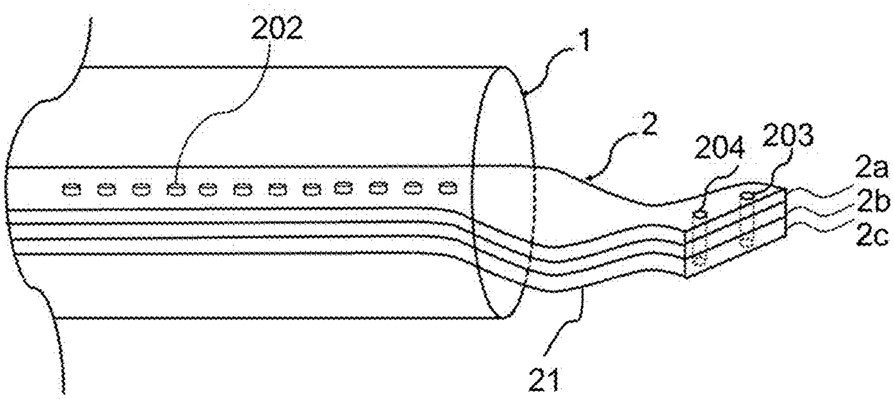

Fig. 48

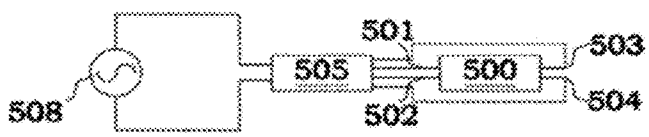

Fig. 49A

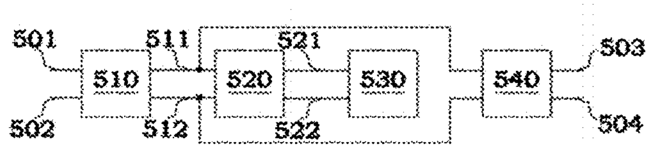

Fig. 49B

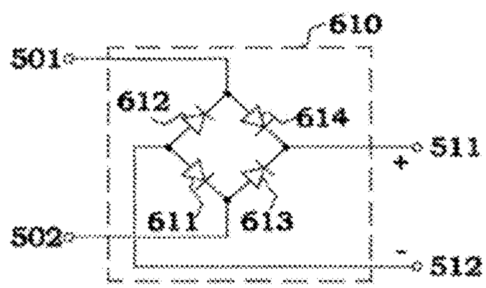

Fig. 50A

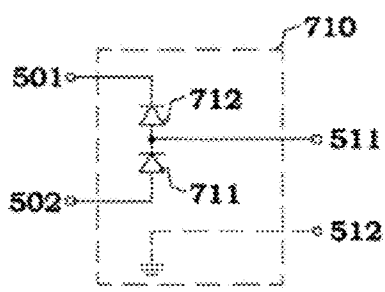

Fig. 50B

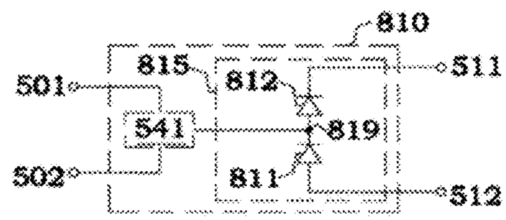

Fig. 50C

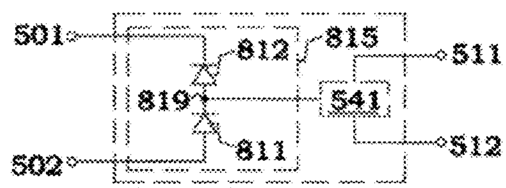

Fig. 50D

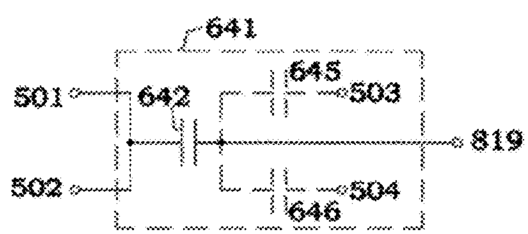

Fig. 51A

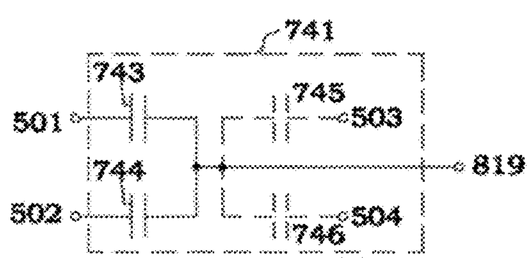

Fig. 51B

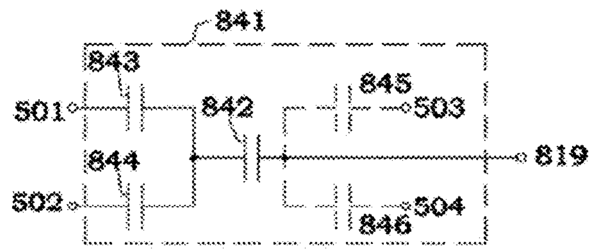

Fig. 51C

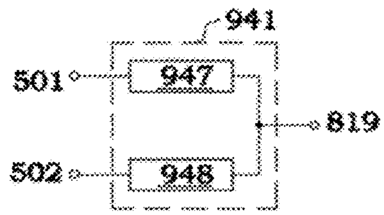

Fig. 51D

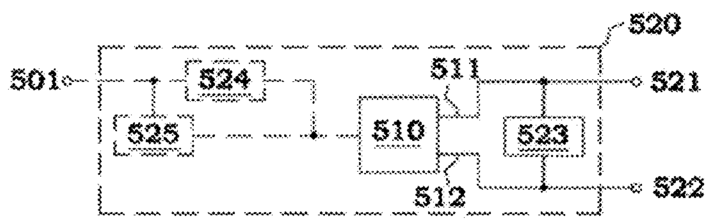

Fig. 52A

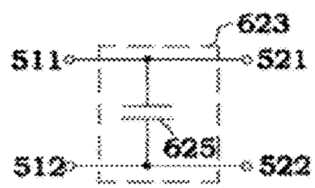

Fig. 52B

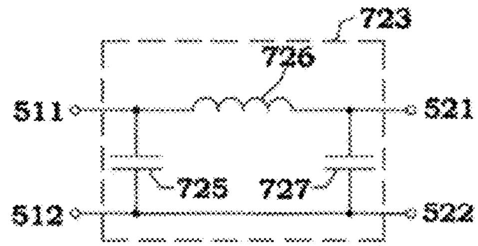

Fig. 52C

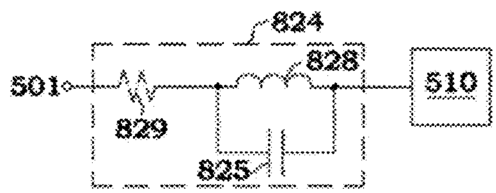

Fig. 52D

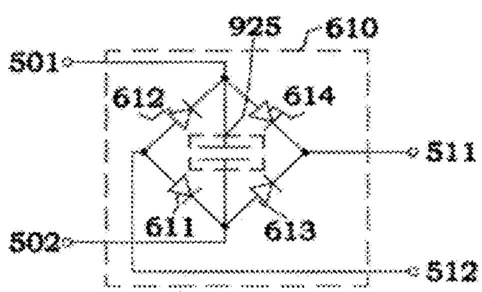

Fig. 52E

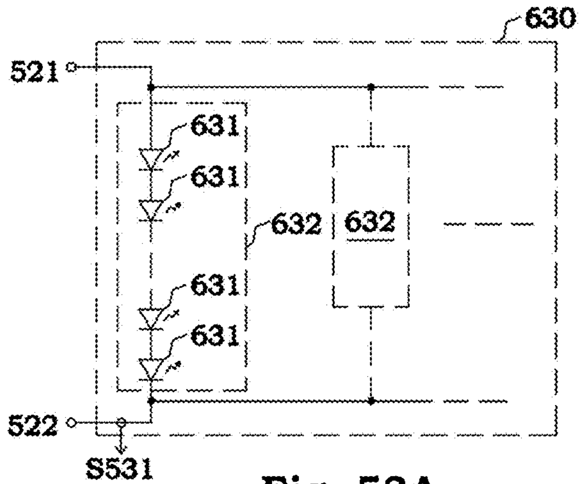

Fig. 53A

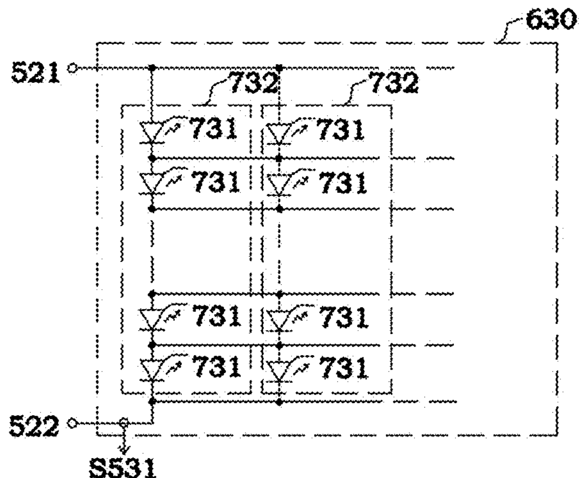

Fig. 53B

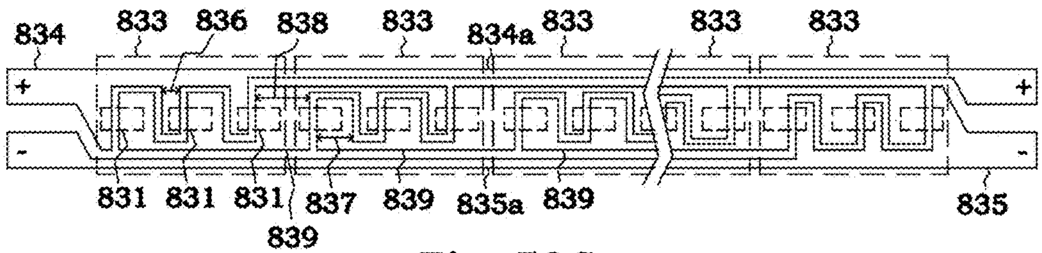

Fig. 53C

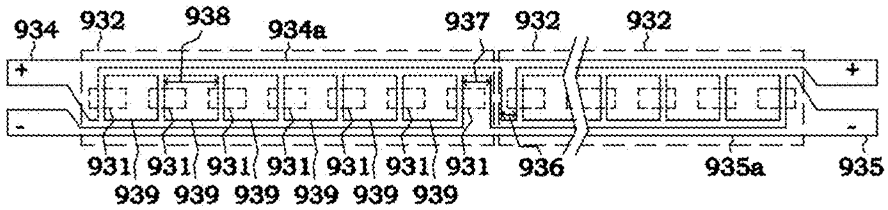

Fig. 53D

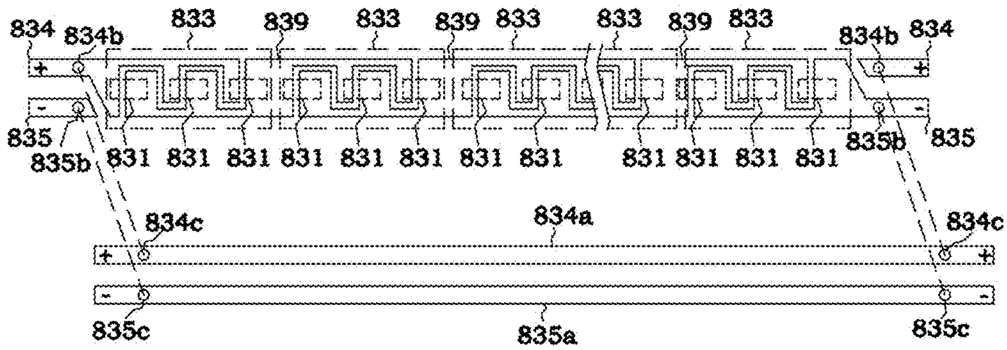

Fig. 53E

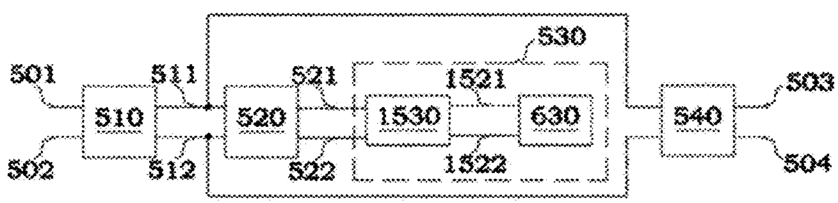

Fig. 54A

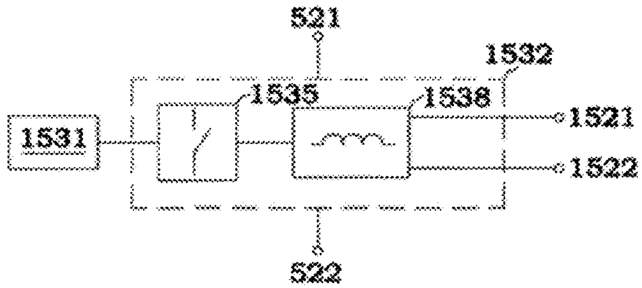

Fig. 54B

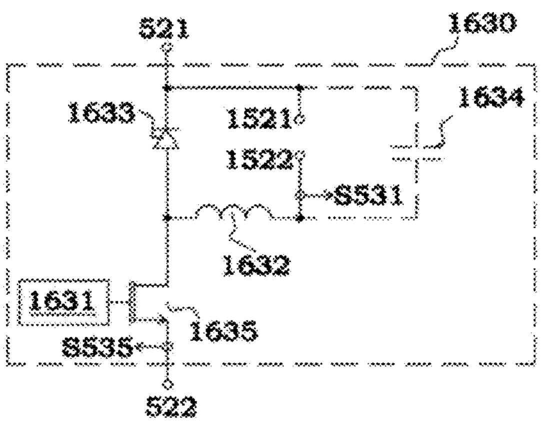

Fig. 54C

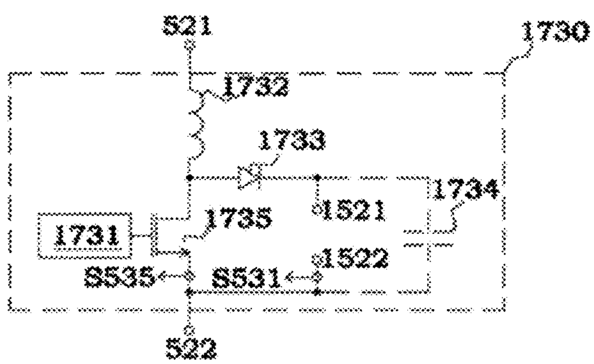

Fig. 54D

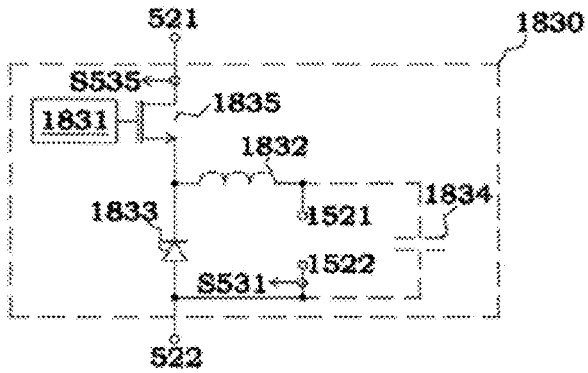

Fig. 54E

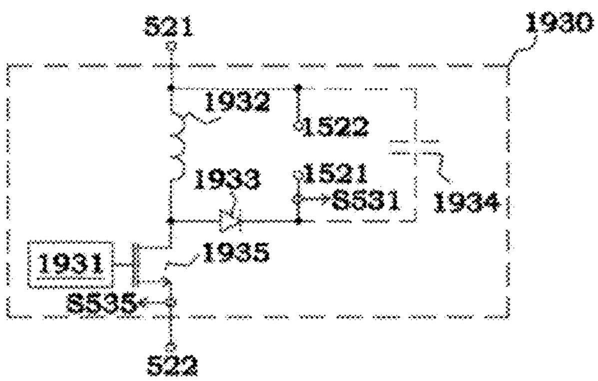

Fig. 54F

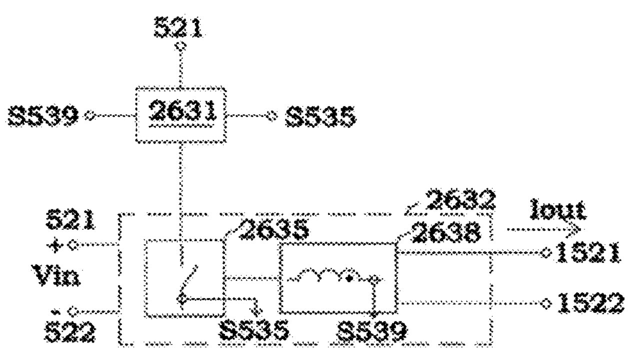

Fig. 54G

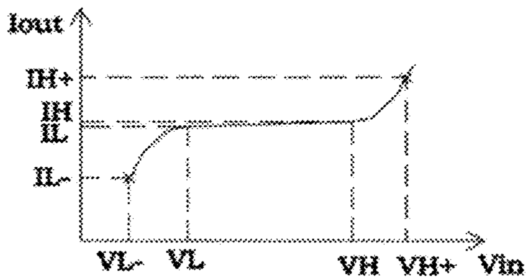

Fig. 54H

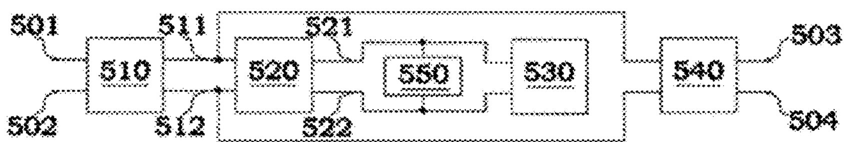

Fig. 55A

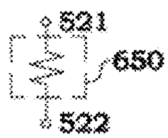

Fig. 55B

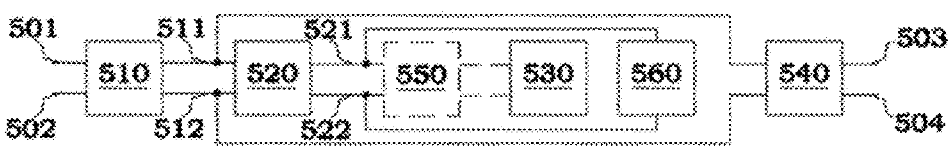

Fig. 56A

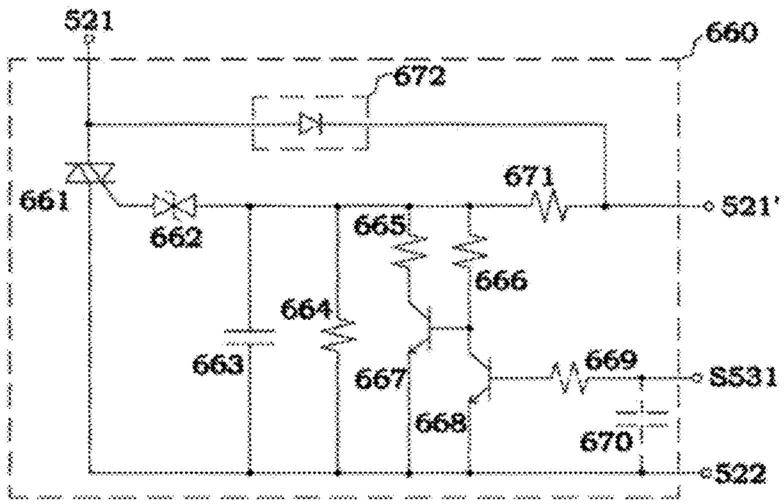

Fig. 56B

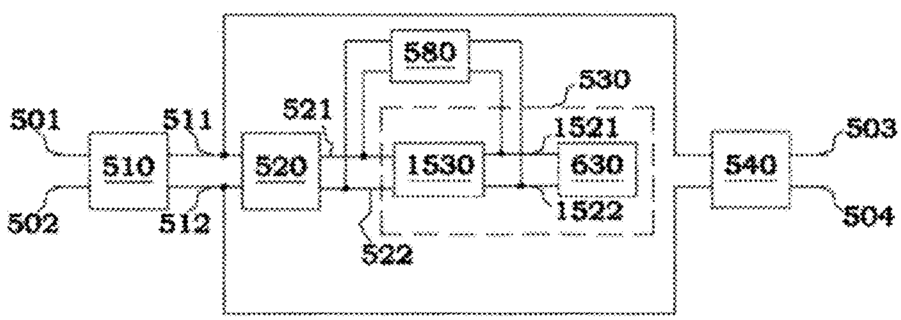

Fig. 57A

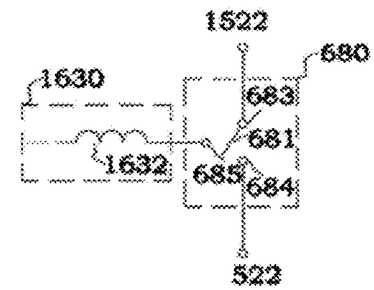

Fig. 57B

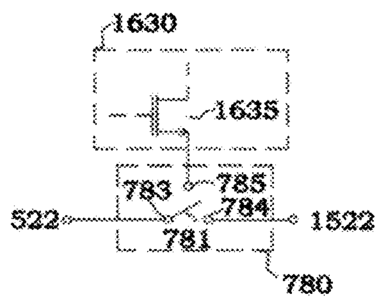

Fig. 57C

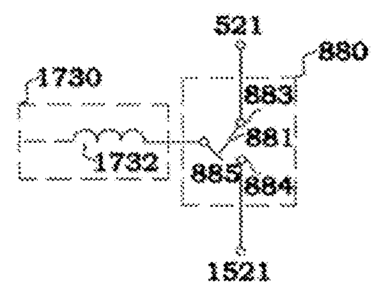

Fig. 57D

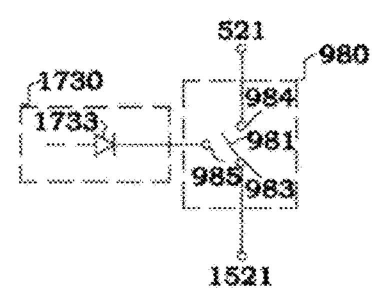

Fig. 57E

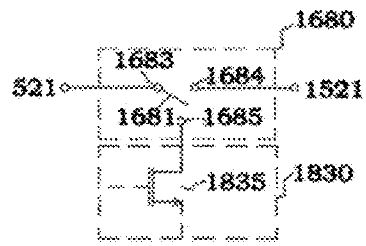

Fig. 57F

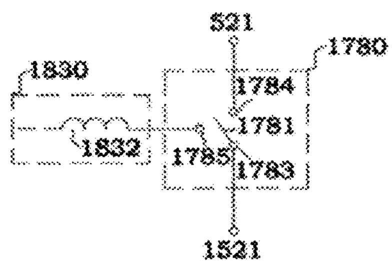

Fig. 57G

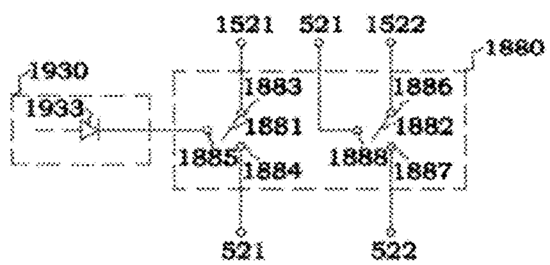

Fig. 57H

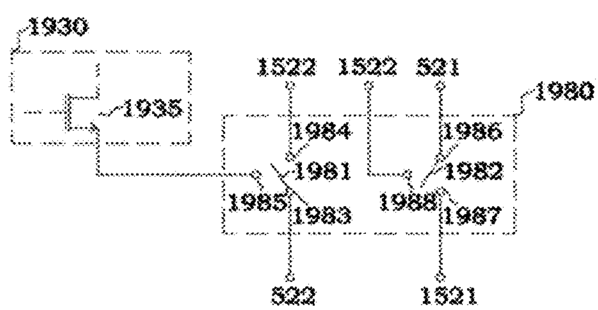

Fig. 57I

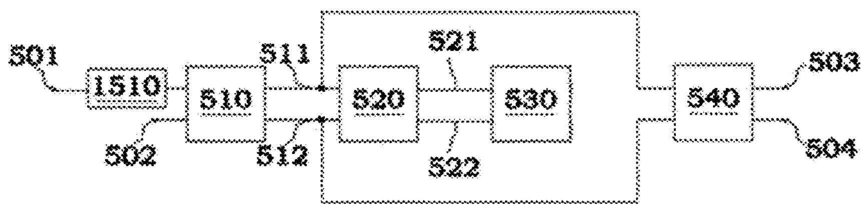

Fig. 58A

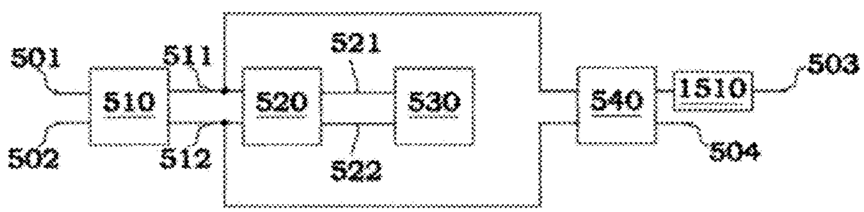

Fig. 58B

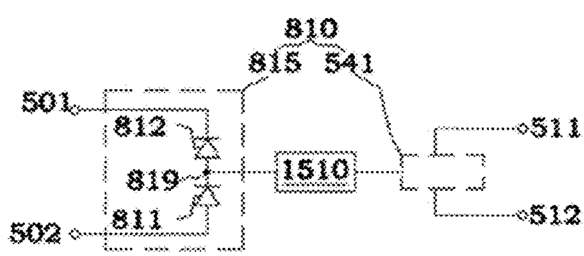

Fig. 58C

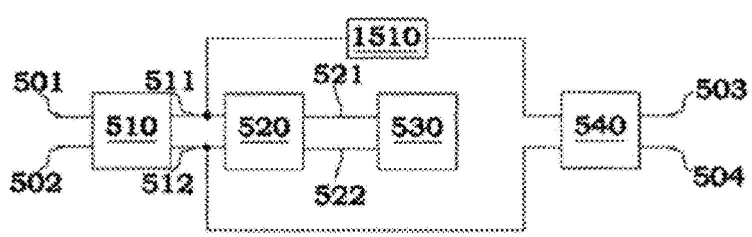

Fig. 58D

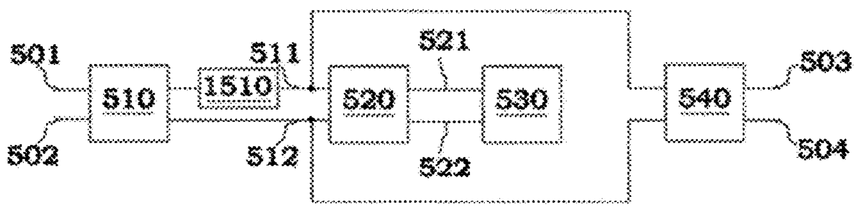

Fig. 58E

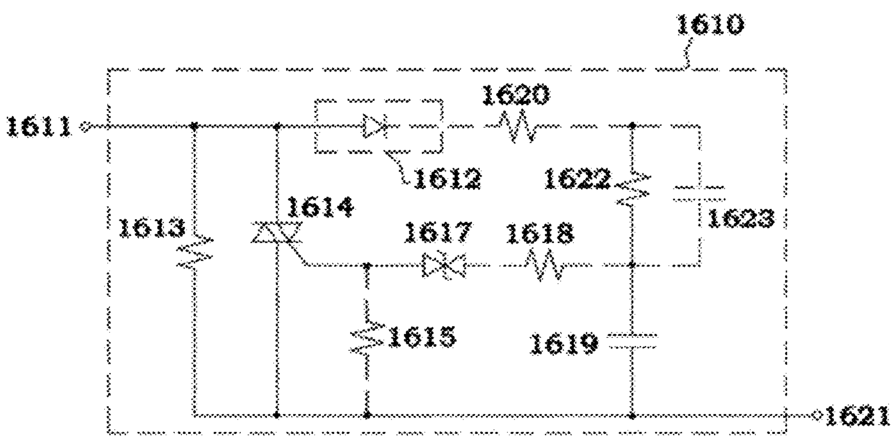

Fig. 58F

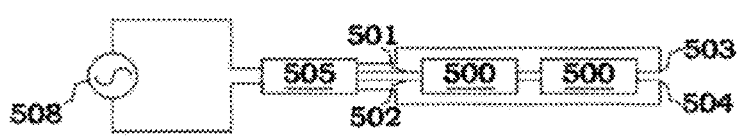

Fig. 58G

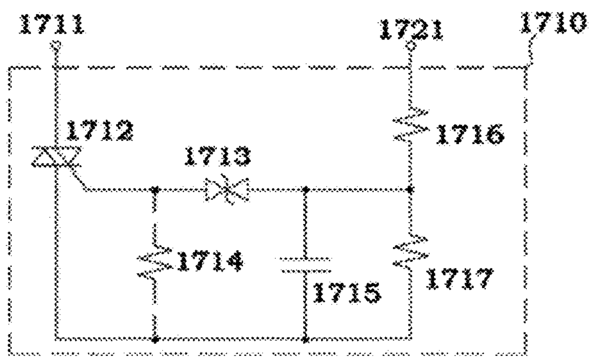

Fig. 58H

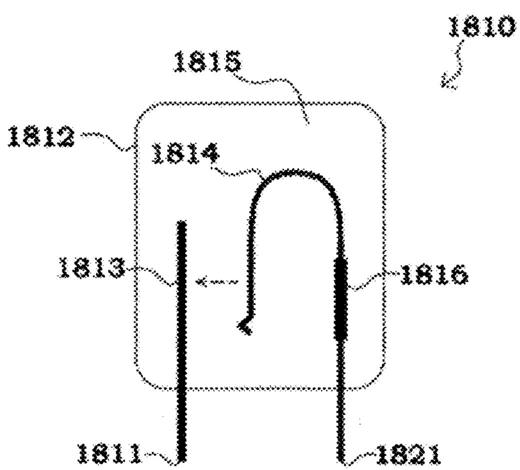

Fig. 58I

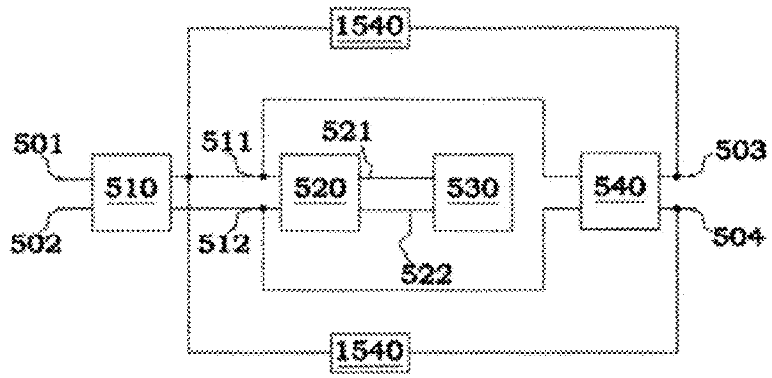

Fig. 59A

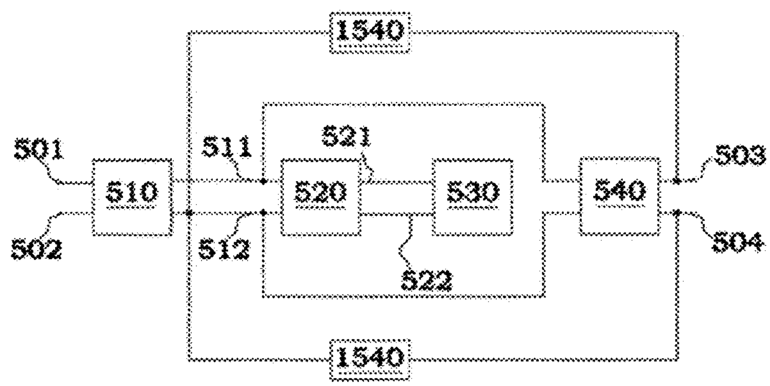

Fig. 59B

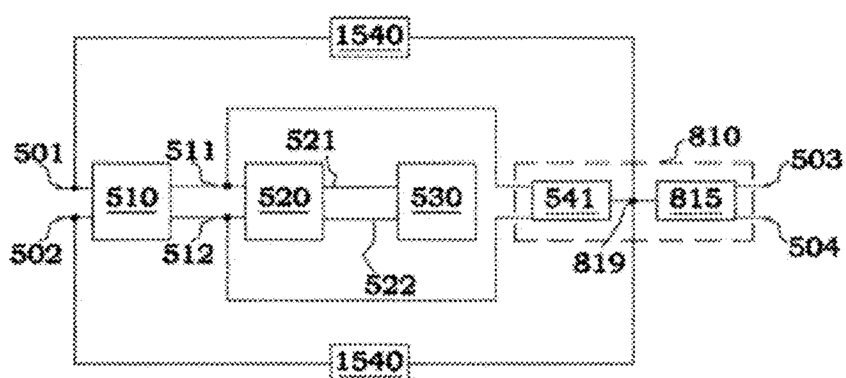

Fig. 59C

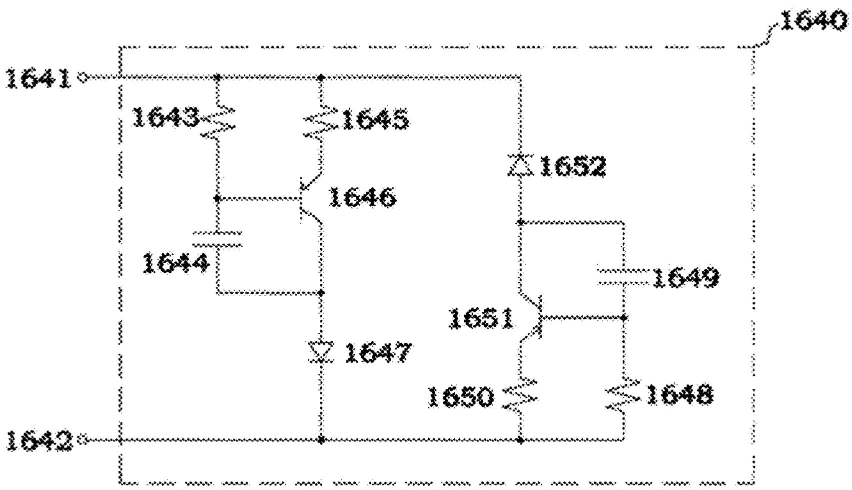

Fig. 59D

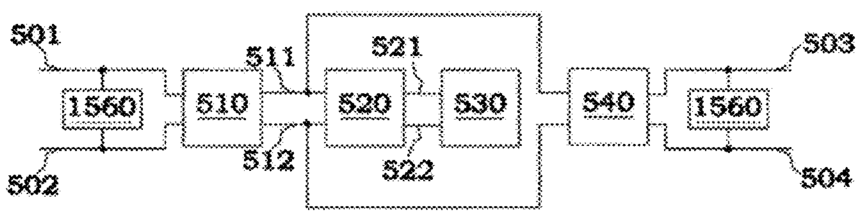

Fig. 60A

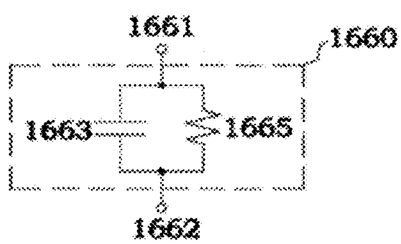

Fig. 60B

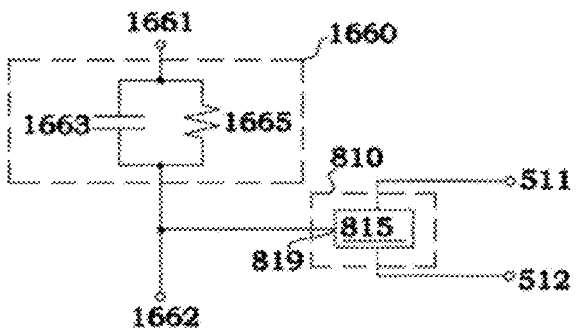

Fig. 60C

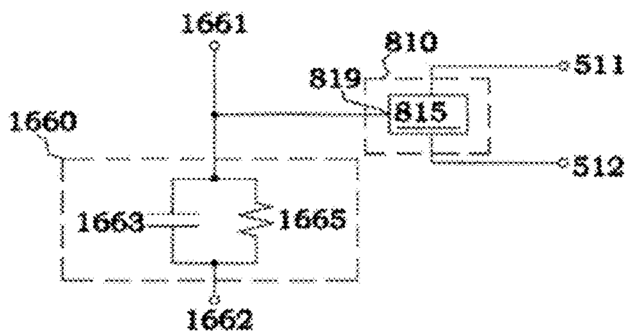

Fig. 60D

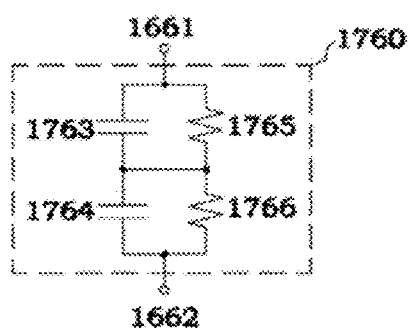

Fig. 60E

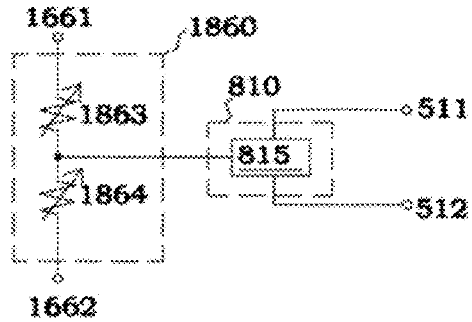

Fig. 60F

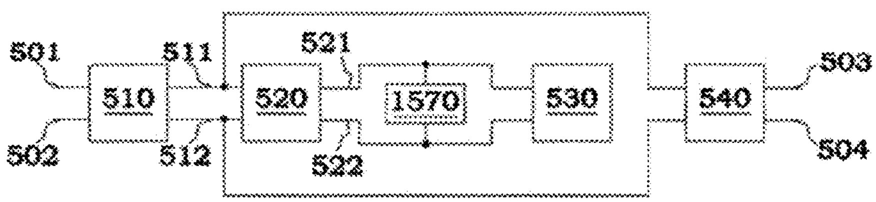

Fig. 61A

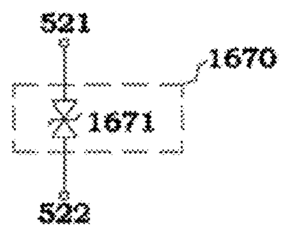

Fig. 61B

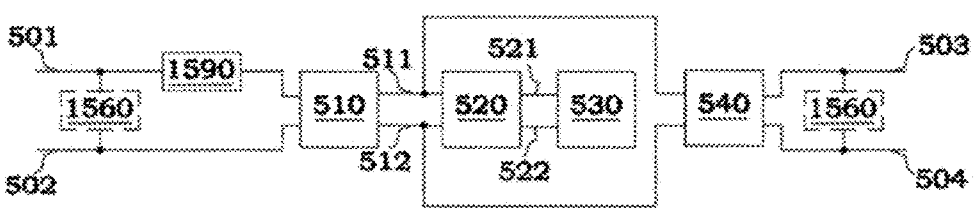

Fig. 62A

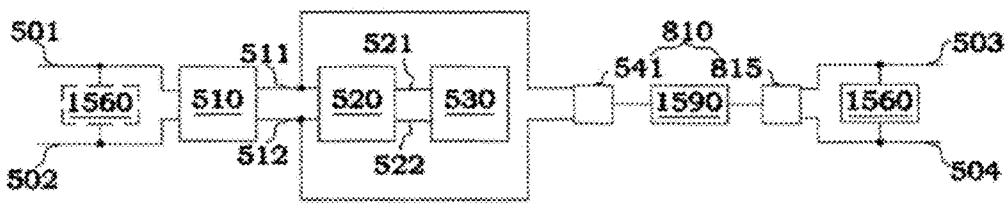

Fig. 62B

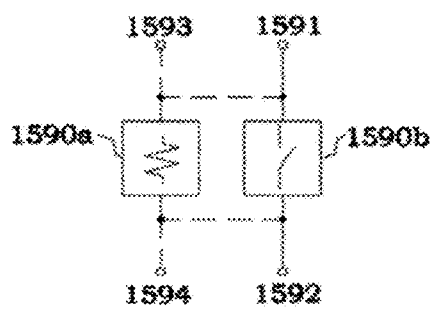

Fig. 62C

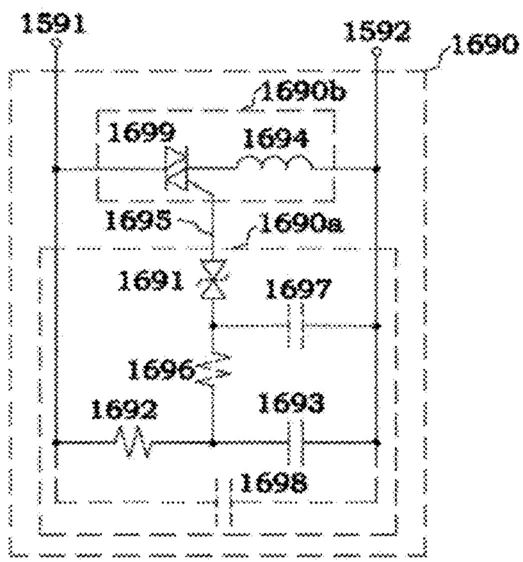

Fig. 62D

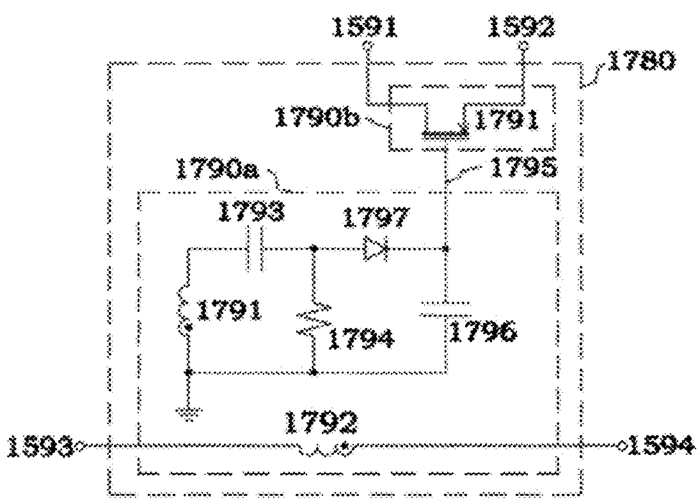

Fig. 62E

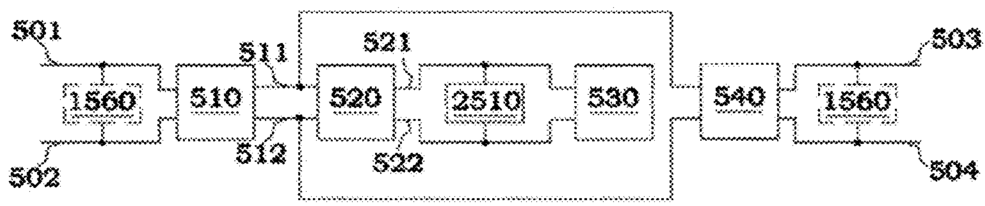

Fig. 63A

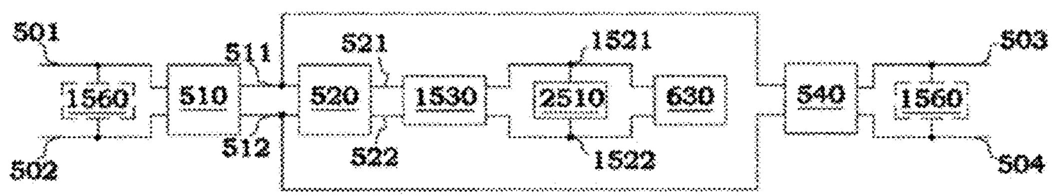

Fig. 63B

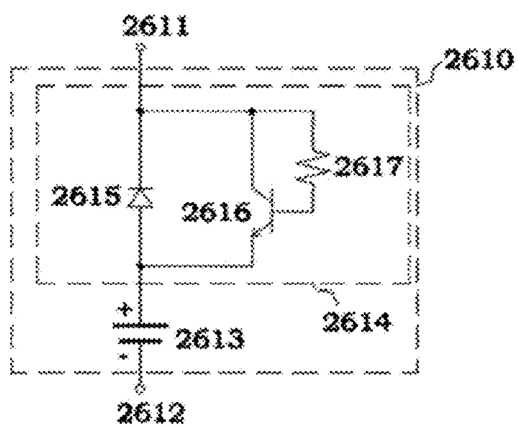

Fig. 63C

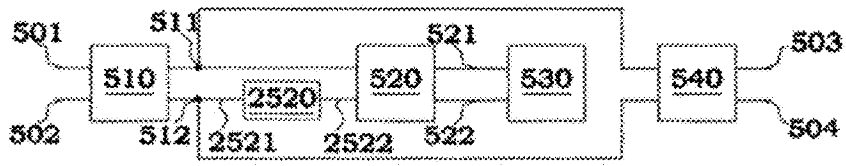

Fig. 64A

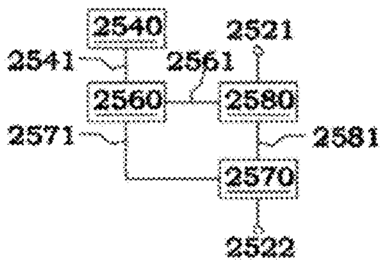

Fig. 64B

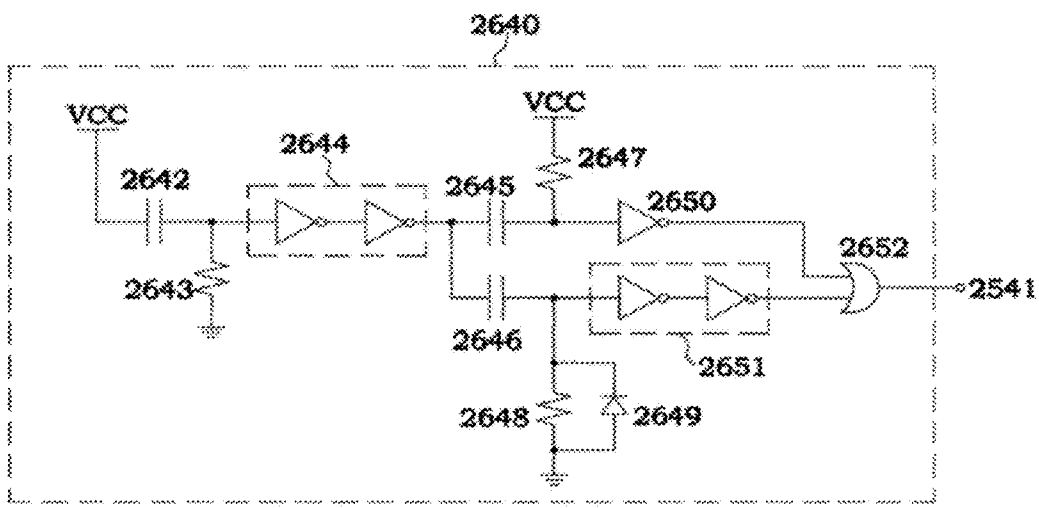

Fig. 64C

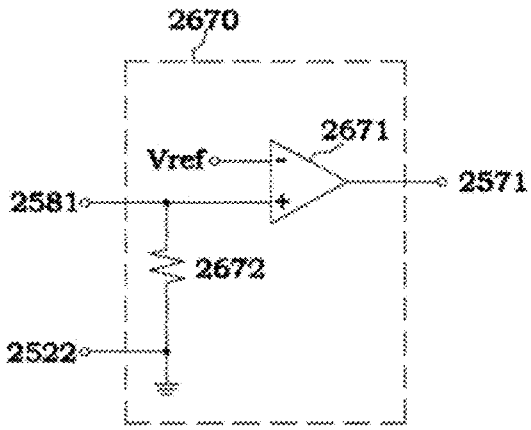

Fig. 64D

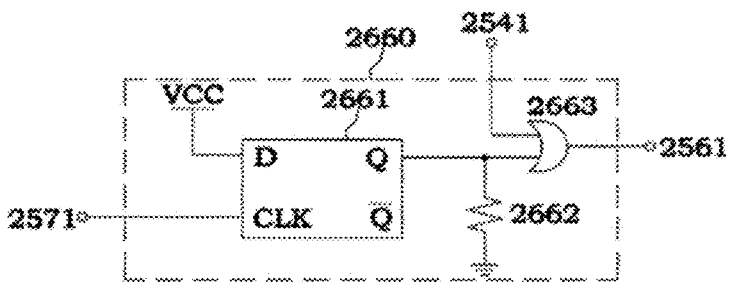

Fig. 64E

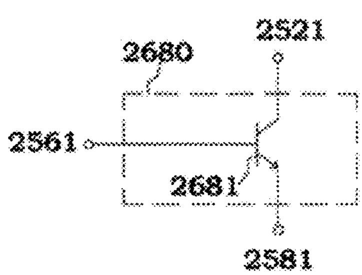

Fig. 64F

LED TUBE LAMP

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation application of non-provisional application Ser. No. 14/865,387 and claims priority to Chinese Patent Applications No. CN 201410507660.9 filed on 2014 Sep. 28; CN 201410508899.8 filed on 2014 Sep. 28; CN 201410623355.6 filed on 2014 Nov. 6; CN 201410734425.5 filed on 2014 Dec. 5; CN 201510075925.7 filed on 2015 Feb. 12; CN 201510104823.3 filed on 2015 Mar. 10; CN 201510134586.5 filed on 2015 Mar. 26; CN 201510133689.x filed on 2015 Mar. 25; CN 201510136796.8 filed on 2015 Mar. 27; CN 201510173861.4 filed on 2015 Apr. 14; CN 201510155807.7 filed on 2015 Apr. 3; CN 201510193980.6 filed on 2015 Apr. 22; CN 201510372375.5 filed on 2015 Jun. 26; CN 201510259151.3 filed on 2015 May 19; CN 201510268927.8 filed on 2015 May 22; CN 201510284720.x filed on 2015 May 29; CN 201510338027.6 filed on 2015 Jun. 17; CN 201510315636.x filed on 2015 Jun. 10; CN 201510373492.3 filed on 2015 Jun. 26; CN 201510364735.7 filed on 2015 Jun. 26; CN 201510378322.4 filed on 2015 Jun. 29; CN 201510391910.1 filed on 2015 Jul. 2; CN 201510406595.5 filed on 2015 Jul. 10; CN 201510482944.1 filed on 2015 Aug. 7; CN 201510486115.0 filed on 2015 Aug. 8; CN 201510428680.1 filed on 2015 Jul. 20; CN 201510483475.5 filed on 2015 Aug. 8; CN 201510555543.4 filed on 2015 Sep. 2; CN 201510557717.0 filed on 2015 Sep. 6; and CN 201510595173.7 filed on 2015 Sep. 18, the disclosures of which are incorporated herein in their entirety by reference.

This application is a continuation application of non-provisional application Ser. No. 15/821,178, filed on Nov. 22, 2017, which is a continuation application of U.S. patent application Ser. No. 15/298,272, filed Oct. 20, 2016, which is a continuation application of U.S. patent application Ser. No. 15/066,645, filed on Mar. 10, 2016, which is a continuation-In-Part application of U.S. patent application Ser. No. 14/865,387, filed Sep. 25, 2015, which claims priority under 35 U.S.C. 119(e) to Chinese Patent Applications No. CN 201410507660.9 filed on Sep. 28, 2014; CN 201410508899.8 filed on Sep. 28, 2014; CN 201410623355.6 filed on Nov. 6. 2014; CN 201410734425.5 filed on Dec. 5, 2014; CN 201510075925.7 filed on Feb. 12, 2015; No. CN 201510104823.3 filed on Mar. 10, 2015; CN 201510134586.5 filed on Mar. 26, 2015; CN 201510133689.x filed on Mar. 25 2015; CN 201510136796.8 filed on Mar. 27, 2015; CN 201510155807.7 filed on Apr. 3, 2015; CN 201510173861.4 filed on Apr. 14, 2015; CN 201510193980.6 filed on Apr. 22, 2015; CN 201510372375.5 filed on Jun. 26, 2015; CN 201510259151.3 filed on May 19, 2015; CN 201510268927.8 filed on May 22, 2015; CN 201510284720.x filed on May 29, 2015; CN 201510338027.6 filed on Jun. 17, 2015; CN 201510315636.x filed on Jun. 10, 2015; CN 201510373492.3 filed on Jun. 26, 2015; CN 201510364735.7 filed on Jun. 26, 2015; CN 201510378322.4 filed on Jun. 29, 2015; CN 201510391910.1 filed on Jul. 2, 2015; CN 201510406595.5 filed on Jul. 10, 2015; CN 201510482944.1 filed on Aug. 7, 2015; CN 201510486115.0 filed on Aug. 8, 2015; CN 201510428680.1 filed on Jul. 20, 2015; CN 201510483475.5 filed on Aug. 8, 2015; CN

201510555543.4 filed on Sep. 2, 2015; CN 201510557717.0 filed on Sep. 6, 2015; CN 201510595173.7 filed on Sep. 18, 2015, the disclosures of which are incorporated herein in their entirety by reference. The application Ser. No. 15/821, 178 also claims priority under 35 U.S.C. 119(e) to Chinese Patent Applications no.: CN 201510530110.3 filed on Aug. 26, 2015; CN 201510499512.1 filed on Aug. 14, 2015; CN 201510448220.5 filed on Jul. 27, 2015; CN 201510645134.3 filed on Oct. 8, 2015; and CN 201510680883.x filed on Oct. 20, 2015, the disclosures of which are incorporated herein in their entirety by reference.

This application is a continuation application of non-provisional application Ser. No. 15/441,789, which is a continuation application of U.S. patent application Ser. No. 14/865,387, filed Feb. 24, 2017, the disclosures of which are incorporated herein in their entirety by reference.

TECHNICAL FIELD

The instant disclosure relates to illumination devices, and more particularly to an LED tube lamp.

RELATED ART

LED lighting technology is rapidly developing to replace traditional incandescent and fluorescent lightings. LED tube lamps are mercury-free in comparison with fluorescent tube lamps that need to be filled with inert gas and mercury. Thus, it is not surprising that LED tube lamps are becoming a highly desired illumination option among different available lighting systems used in homes and workplaces. Lighting systems in homes and workplace are used to be dominated by traditional lighting options such as compact fluorescent light bulbs (CFLs) and fluorescent tube lamps. Benefits of LED tube lamps include improved durability and longevity and far less energy consumption; therefore, when taking into account all factors, they would typically be considered as a cost effective lighting option.

Typical LED tube lamps have a lamp tube, light sources in the lamp tube, two caps connected to two ends of the lamp tube, and one power supply or two at the ends of the lamp tube. The caps receive external electricity and transmit it to the power supply and the light sources through a wire or wires (wire bonding).

However, existing LED tube lamps have certain drawbacks. Specifically, the wires may be easily damaged and even broken due to any movement during manufacturing, transportation, and usage of the LED tube lamp and therefore may disable the LED tube lamp.

SUMMARY

To address the above issue, the instant disclosure provides an LED lamp tube.

Various embodiments are summarized in this section, and are described with respect to the "present invention," which terminology is used to describe certain presently disclosed embodiments, whether claimed or not, and is not necessarily an exhaustive description of all possible embodiments, but rather is merely a summary of certain embodiments. Certain of the embodiments described below as various aspects of the "present invention" can be combined in different manners to form an LED tube lamp or a portion thereof.

According to an embodiment of the instant disclosure, an LED tube lamp comprises a plurality of LED light sources, an end cap, a power supply disposed in the end cap, a lamp tube, and an LED light strip. The lamp tube extends in a first direction along a length of the lamp tube, and has an end attached to the end cap. The LED light strip is electrically connected the LED light sources with the power supply. The LED light strip has in sequence a first wiring layer, a dielectric layer and a second wiring layer. A thickness of the second wiring layer is greater than a thickness of the first wiring layer.

According to an embodiment of the instant disclosure, a length of the LED light strip is greater than that of the lamp tube and the LED light strip has an end portion extending inside the end cap.

According to an embodiment of the instant disclosure, the plurality of LED light sources is disposed on the light strip except the end region of the light strip extending inside the end cap.

According to an embodiment of the instant disclosure, the first wiring layer is the layer on which the plurality of LED light source is disposed, and the plurality of LED light sources are electrically connected to the first wiring layer.

According to an embodiment of the instant disclosure, the end portion of the light strip has a plurality of through holes to respectively electrically communicate the first wiring layer and the second wiring layer. The through holes are electrically insulated to each other to avoid short.

According to an embodiment of the instant disclosure, an LED tube lamp comprises a lamp tube, two end caps each of which coupled to a respective end of the lamp tube, a power supply disposed in one or two of the end caps, an LED light strip disposed on an inner circumferential surface ofthe lamp tube, and a protective layer disposed on the LED light strip. The LED light strip comprises a mounting region and a connecting region. The mounting region is for mounting a plurality of LED light sources. The connecting region have at least two soldering pads.. The mounting region and the connecting region are electrically connected to the plurality of LED light sources and the power supply. The protective layer have a plurality of first openings to accommodate the plurality of LED light sources and at least two second openings to accommodate the at least two soldering pads.

According to some embodiments of the instant disclosure, the protective layer further comprises a third opening adjacent to the two second openings.

According to some embodiments of the instant disclosure, the LED light strip further comprises a fourth opening arranged on the connecting region and corresponding to the third opening on the protective layer. The third opening and the fourth opening forms a through hole.

According to some embodiments of the instant disclosure, the through hole is arranged between the two soldering pads.

According to some embodiments of the instant disclosure, the through hole allows a soldering machine to recognize the position of the soldering pads during a soldering process.

According to some embodiments of the instant disclosure, the LED tube lamp further comprises a first pin and a second pin coupled to one of the two end caps, and a third pin coupled to the other end cap. The power supply comprises a first rectifying circuit, a second rectifying circuit, and a driving circuit. The first rectifying circuit is connected to the first and second pins. The second rectifying circuit is connected to the third pin and an output terminal of the first rectifying circuit. The first and second rectifying circuits are configured for rectifying an external driving signal to produce a rectified signal. The driving circuit is coupled to the first and second rectifying circuits and the LED light sources for driving the LED light sources. The LED tube lamp is configured to receive the external driving signal and emit light in each of two power supply arrangements. A first power supply arrangement is that the external driving signal is a low frequency signal input and transmitted through the first and second pins, and a second power supply arrangement is that the external driving signal is a low frequency signal input and transmitted through one of the first and second pins and through the third pin across the two ends of the lamp tube. The LED tube lamp is configured such that when the external driving signal is a low frequency signal. The LED tube lamp causes the rectified signal to be used by the driving circuit for driving the LED light sources to emit light.

According to some embodiments of the instant disclosure, the LED tube lamp further comprises a first pin and a second pin coupled to one of the two end caps, and a third pin coupled to the other end cap. The power supply comprises a first rectifying circuit, a second rectifying circuit, and a detection circuit. The first rectifying circuit comprises diodes and is connected to the first and second pins. The second rectifying circuit comprises diodes and is connected to the third pin and an output terminal of the first rectifying circuit. The first and second rectifying circuits are configured to rectify an external driving signal to produce a rectified signal. The detection circuit is coupled to the first and second rectifying circuits and the LED light sources, and configured for determining whether to cause the LED light sources to be driven by the rectified signal, or to prevent the LED light sources from being driven by the rectified signal. The LED tube lamp is configured to receive the external driving signal and emit light in each of two power supply arrangements. A first power supply arrangement is that the external driving signal is input and transmitted through the first and second pins, and a second power supply arrangement is that the external driving signal is input and transmitted through one of the first and second pins and through the third pin across the two ends of the lamp tube.

According to an embodiment of the instant disclosure, an LED tube lamp comprises a lamp tube, two end caps, a power supply, a light strip, a plurality of LED light sources, two soldering pads, a recognizing mark, and a protective layer. The two end caps are attached at two ends of the lamp tube respectively. The power supply is disposed in one or both of the end caps or separately in both of the end caps. The light strip is disposed inside the lamp tube. The light strip comprises a mounting region and a connecting region. The LED light sources are mounted on the mounting region. The mounting region and the connecting region are electrically connected to the LED light sources and the power supply. At least two soldering pads are arranged on the connecting region for electrically connecting the power supply. The recognizing mark is arranged on the connecting region. The protective layer is disposed on the light strip.

According to some embodiments of the instant disclosure, the protective layer comprises a plurality of first openings arranged on the mounting region for accommodating the LED light sources and at least two second openings arranged on the connecting region for accommodating the at least two soldering pads.

According to some embodiments of the instant disclosure, the protective layer further comprising a third opening, and the third opening comprises the recognizing mark.

The features of the instant disclosure will no doubt become understandable to those of ordinary skill in the art after reading the following detailed description of the preferred embodiment that is illustrated in the various figures and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view schematically illustrating an LED tube lamp according to one embodiment of the present invention;

FIG. **1**A is a perspective view schematically illustrating the different sized end caps of an LED tube lamp according to another embodiment of the present invention to illustrate;

FIG. **2** is an exemplary exploded view schematically illustrating the LED tube lamp shown in FIG. **1**;

FIG. **3** is a perspective view schematically illustrating front and top of an end cap of the LED tube lamp according to one embodiment of the present invention;

FIG. **4** is an exemplary perspective view schematically illustrating bottom of the end cap as shown in FIG. **3**;

FIG. **5** is a plane cross-sectional partial view schematically illustrating a connecting region of the end cap and the lamp tube of the LED tube lamp according to one embodiment of the present invention;

FIG. **6** is a perspective cross-sectional view schematically illustrating inner structure of an all-plastic end cap (having a magnetic metal member and hot melt adhesive inside) according to another embodiment of the present invention;

FIG. **7** is a perspective view schematically illustrating the all-plastic end cap and the lamp tube being bonded together by utilizing an induction coil according to certain embodiments of the present invention;

FIG. **8** is a perspective view schematically illustrating a supporting portion and a protruding portion of the electrically insulating tube of the end cap of the LED tube lamp according to another embodiment of the present invention;

FIG. **9** is an exemplary plane cross-sectional view schematically illustrating the inner structure of the electrically insulating tube and the magnetic metal member of the end cap of FIG. **8** taken along a line X-X;

FIG. **10** is a plane view schematically illustrating the configuration of the openings on surface of the magnetic metal member of the end cap of the LED tube lamp according to another embodiment of the present invention;

FIG. **11** is a plane view schematically illustrating the indentation/embossment on a surface of the magnetic metal member of the end cap of the LED tube lamp according to certain embodiments of the present invention;

FIG. **12** is an exemplary plane cross-sectional view schematically illustrating the structure of the connection of the end cap of FIG. **8** and the lamp tube along a radial axis of the lamp tube, where the electrically insulating tube is in shape of a circular ring;

FIG. **13** is an exemplary plane cross-sectional view schematically illustrating the structure of the connection of the end cap of FIG. **8** and the lamp tube along a radial axis of the lamp tube, where the electrically insulating tube is in shape of an elliptical or oval ring;

FIG. **14** is a perspective view schematically illustrating still another end cap of an LED tube lamp according to still another embodiment of the prevent invention;

FIG. **15** is a plane cross-sectional view schematically illustrating end structure of a lamp tube of the LED tube lamp according to one embodiment of the present invention;

FIG. **16** is an exemplary plane cross-sectional view schematically illustrating the local structure of the transition region of the end of the lamp tube of FIG. **15**;

FIG. **17** is a plane cross-sectional view schematically illustrating inside structure of the lamp tube of the LED tube lamp according to one embodiment of the present invention, wherein two reflective films are respectively adjacent to two sides of the LED light strip along the circumferential direction of the lamp tube;

FIG. **18** is a plane cross-sectional view schematically illustrating inside structure of the lamp tube of the LED tube lamp according to another embodiment of the present invention, wherein only a reflective film is disposed on one side of the LED light strip along the circumferential direction of the lamp tube;

FIG. **19** is a plane cross-sectional view schematically illustrating inside structure of the lamp tube of the LED tube lamp according to still another embodiment of the present invention, wherein the reflective film is under the LED light strip and extends at both sides along the circumferential direction of the lamp tube;

FIG. **20** is a plane cross-sectional view schematically illustrating inside structure of the lamp tube of the LED tube lamp according to yet another embodiment of the present invention, wherein the reflective film is under the LED light strip and extends at only one side along the circumferential direction of the lamp tube;

FIG. **21** is a plane cross-sectional view schematically illustrating inside structure of the lamp tube of the LED tube lamp according to still yet another embodiment of the present invention, wherein two reflective films are respectively adjacent to two sides of the LED light strip and extending along the circumferential direction of the lamp tube;

FIG. **22** is a plane sectional view schematically illustrating the LED light strip is a bendable circuit sheet with ends thereof passing across the transition region of the lamp tube of the LED tube lamp to be soldering bonded to the output terminals of the power supply according to one embodiment of the present invention;

FIG. **23** is a plane cross-sectional view schematically illustrating a bi-layered structure of the bendable circuit sheet of the LED light strip of the LED tube lamp according to an embodiment of the present invention;

FIG. **24** is a perspective view schematically illustrating the soldering pad of the bendable circuit sheet of the LED light strip for soldering connection with the printed circuit board of the power supply of the LED tube lamp according to one embodiment of the present invention;

FIG. **25** is a plane view schematically illustrating the arrangement of the soldering pads of the bendable circuit sheet of the LED light strip of the LED tube lamp according to one embodiment of the present invention;

FIG. **26** is a plane view schematically illustrating a row of three soldering pads of the bendable circuit sheet of the LED light strip of the LED tube lamp according to another embodiment of the present invention;

FIG. **27** is a plane view schematically illustrating two rows of soldering pads of the bendable circuit sheet of the LED light strip of the LED tube lamp according to still another embodiment of the present invention;

FIG. **28** is a plane view schematically illustrating a row of four soldering pads of the bendable circuit sheet of the LED light strip of the LED tube lamp according to yet another embodiment of the present invention;

FIG. **29** is a plane view schematically illustrating two rows of two soldering pads of the bendable circuit sheet of the LED light strip of the LED tube lamp according to yet still another embodiment of the present invention;

FIG. **30** is a plane view schematically illustrating through holes are formed on the soldering pads of the bendable circuit sheet of the LED light strip of the LED tube lamp according to one embodiment of the present invention;

FIG. **31** is a plane cross-sectional view schematically illustrating soldering bonding process utilizing the soldering pads of the bendable circuit sheet of the LED light strip of FIG. **30** taken from side view and the printed circuit board of the power supply according to one embodiment of the present invention;

FIG. **32** is a plane cross-sectional view schematically illustrating soldering bonding process utilizing the soldering pads of the bendable circuit sheet of the LED light strip of FIG. **30** taken from side view and the printed circuit board of the power supply according to another embodiment of the present invention, wherein the through hole of the soldering pads is near the edge of the bendable circuit sheet;

FIG. **33** is a plane view schematically illustrating notches formed on the soldering pads of the bendable circuit sheet of the LED light strip of the LED tube lamp according to one embodiment of the present invention;

FIG. **34** is an exemplary plane cross-sectional view of FIG. **33** taken along a line A-A';

FIG. **35** is a perspective view schematically illustrating a circuit board assembly composed of the bendable circuit sheet of the LED light strip and the printed circuit board of the power supply according to another embodiment of the present invention;

FIG. **36** is a perspective view schematically illustrating another arrangement of the circuit board assembly of FIG. **35**;

FIG. **37** is a perspective view schematically illustrating an LED lead frame for the LED light sources of the LED tube lamp according to one embodiment of the present invention;

FIG. **38** is a perspective view schematically illustrating a power supply of the LED tube lamp according to one embodiment of the present invention;

FIG. **39** is a perspective view schematically illustrating the printed circuit board of the power supply, which is perpendicularly adhered to a hard circuit board made of aluminum via soldering according to another embodiment of the present invention;

FIG. **40** is a perspective view illustrating a thermos-compression head used in soldering the bendable circuit sheet of the LED light strip and the printed circuit board of the power supply according to one embodiment of the present invention;

FIG. **41** is a plane view schematically illustrating the thickness difference between two solders on the pads of the bendable circuit sheet of the LED light strip or the printed circuit board of the power supply according to one embodiment of the invention;

FIG. **42** is a perspective view schematically illustrating the soldering vehicle for soldering the bendable circuit sheet of the LED light strip and the printed circuit board of the power supply according to one embodiment of the invention;

FIG. **43** is an exemplary plan view schematically illustrating a rotation status of the rotary platform of the soldering vehicle in FIG. **41**;

FIG. **44** is a plan view schematically illustrating an external equipment for heating the hot melt adhesive according to another embodiment of the present invention;

FIG. **45** is a cross-sectional view schematically illustrating the hot melt adhesive having uniformly distributed high permeability powder particles with small particle size according to one embodiment of the present invention;

FIG. **46** is a cross-sectional view schematically illustrating the hot melt adhesive having non-uniformly distributed high permeability powder particles with small particle size according to another embodiment of the present invention, wherein the powder particles form a closed electric loop;

FIG. **47** is a cross-sectional view schematically illustrating the hot melt adhesive having non-uniformly distributed high permeability powder particles with large particle size according to yet another embodiment of the present invention, wherein the powder particles form a closed electric loop;

FIG. **48** is a perspective view schematically illustrating the bendable circuit sheet of the LED light strip is formed with two conductive wiring layers according to another embodiment of the present invention.

FIG. **49**A is a block diagram of an exemplary power supply module in an LED tube lamp according to some embodiments of the present invention;

FIG. **49**B is a circuit block diagram of an LED lamp according to some embodiments of the present invention;

FIG. **50**A is a schematic diagram of a rectifying circuit according to some embodiments of the present invention;

FIG. **50**B is a schematic diagram of a rectifying circuit according to some embodiments of the present invention;

FIG. **50**C is a schematic diagram of a rectifying circuit according to some embodiments of the present invention;

FIG. **50**D is a schematic diagram of a rectifying circuit according to some embodiments of the present invention;

FIG. **51**A is a schematic diagram of a terminal adapter circuit according to some embodiments of the present invention;

FIG. **51**B is a schematic diagram of a terminal adapter circuit according to some embodiments of the present invention;

FIG. **51**C is a schematic diagram of a terminal adapter circuit according to some embodiments of the present invention;

FIG. **51**D is a schematic diagram of a terminal adapter circuit according to some embodiments of the present invention;

FIG. **52**A is a block diagram of a filtering circuit according to some embodiments of the present invention;

FIG. **52**B is a schematic diagram of a filtering unit according to some embodiments of the present invention;

FIG. **52**C is a schematic diagram of a filtering unit according to some embodiments of the present invention;

FIG. **52**D is a schematic diagram of a filtering unit according to some embodiments of the present invention;

FIG. **53**E is a schematic diagram of a filtering unit according to some embodiments of the present invention;

FIG. **53**A is a schematic diagram of an LED module according to some embodiments of the present invention;

FIG. **53**B is a schematic diagram of an LED module according to some embodiments of the present invention;

FIG. **53**C is a plan view of a circuit layout of the LED module according to some embodiments of the present invention;

FIG. **53**D is a plan view of a circuit layout of the LED module according to some embodiments of the present invention;

FIG. **53**E is a plan view of a circuit layout of the LED module according to some embodiments of the present invention;

FIG. **54**A is a block diagram of an exemplary power supply module in an LED lamp according to some embodiments of the present invention;

FIG. **54**B is a block diagram of a driving circuit according to some embodiments of the present invention;

FIG. **54**C is a schematic diagram of a driving circuit according to some embodiments of the present invention;

FIG. **54**D is a schematic diagram of a driving circuit according to some embodiments of the present invention;

FIG. **54**E is a schematic diagram of a driving circuit according to some embodiments of the present invention;

FIG. **54**F is a schematic diagram of a driving circuit according to some embodiments of the present invention;

FIG. **54**G is a block diagram of a driving circuit according to some embodiments of the present invention;

FIG. **54**H is a graph illustrating the relationship between the voltage Vin and the objective current Iout according to certain embodiments of the present invention;

FIG. **55**A is a block diagram of an exemplary power supply module in an LED lamp according to some embodiments of the present invention;

FIG. **55**B is a schematic diagram of an anti-flickering circuit according to some embodiments of the present invention;

FIG. **56**A is a block diagram of an exemplary power supply module in an LED lamp according to some embodiments of the present invention;

FIG. **56**B is a schematic diagram of a protection circuit according to some embodiments of the present invention;

FIG. **57**A is a block diagram of an exemplary power supply module in an LED lamp according to some embodiments of the present invention;

FIG. **57**B is a schematic diagram of a mode switching circuit in an LED lamp according to some embodiments of the present invention;

FIG. **57**C is a schematic diagram of a mode switching circuit in an LED lamp according to some embodiments of the present invention;

FIG. **57**D is a schematic diagram of a mode switching circuit in an LED lamp according to some embodiments of the present invention;

FIG. **57**E is a schematic diagram of a mode switching circuit in an LED lamp according to some embodiments of the present invention;

FIG. **57**F is a schematic diagram of a mode switching circuit in an LED lamp according to some embodiments of the present invention;

FIG. **57**G is a schematic diagram of a mode switching circuit in an LED lamp according to some embodiments of the present invention;

FIG. **57**H is a schematic diagram of a mode switching circuit in an LED lamp according to some embodiments of the present invention;

FIG. **57**I is a schematic diagram of a mode switching circuit in an LED lamp according to some embodiment of the present invention;

FIG. **58**A is a block diagram of an exemplary power supply module in an LED lamp according to some embodiments of the present invention;

FIG. **58**B is a block diagram of an exemplary power supply module in an LED lamp according to some embodiments of the present invention;

FIG. **58**C illustrates an arrangement with a ballast-compatible circuit in an LED lamp according to some embodiments of the present invention;

FIG. **58**D is a block diagram of an exemplary power supply module in an LED lamp according to some embodiments of the present invention;

FIG. **58**E is a block diagram of an exemplary power supply module in an LED lamp according to some embodiments of the present invention;

FIG. **58**F is a schematic diagram of a ballast-compatible circuit according to some embodiments of the present invention;

FIG. **58**G is a block diagram of an exemplary power supply module in an LED lamp according to some embodiments of the present invention;

FIG. **58**H is a schematic diagram of a ballast-compatible circuit according to some embodiments of the present invention;

FIG. **58**I illustrates a ballast-compatible circuit according to some embodiments of the present invention;

FIG. **59**A is a block diagram of an exemplary power supply module in an LED tube lamp according to some embodiments of the present invention;

FIG. **59**B is a block diagram of an exemplary power supply module in an LED tube lamp according to some embodiments of the present invention;

FIG. **59**C is a block diagram of an exemplary power supply module in an LED tube lamp according to some embodiments of the present invention;

FIG. **59**D is a schematic diagram of a ballast-compatible circuit according to some embodiments of the present invention;

FIG. **60**A is a block diagram of an exemplary power supply module in an LED tube lamp according to some embodiments of the present invention;

FIG. **60**B is a schematic diagram of a filament-simulating circuit according to some embodiments of the present invention;

FIG. **60**C is a schematic block diagram including a filament-simulating circuit according to some embodiments of the present invention;

FIG. **60**D is a schematic block diagram including a filament-simulating circuit according to some embodiments of the present invention;

FIG. **60**E is a schematic diagram of a filament-simulating circuit according to some embodiments of the present invention;

FIG. **60**F is a schematic block diagram including a filament-simulating circuit according to some embodiments of the present invention;

FIG. **61**A is a block diagram of an exemplary power supply module in an LED tube lamp according to some embodiments of the present invention;

FIG. **61**B is a schematic diagram of an OVP circuit according to an embodiment of the present invention;

FIG. **62**A is a block diagram of an exemplary power supply module in an LED tube lamp according to some embodiments of the present invention;

FIG. **62**B is a block diagram of an exemplary power supply module in an LED tube lamp according to some embodiments of the present invention;

FIG. **62**C is a block diagram of a ballast detection circuit according to some embodiments of the present invention;

FIG. **62**D is a schematic diagram of a ballast detection circuit according to some embodiments of the present invention;

FIG. **62**E is a schematic diagram of a ballast detection circuit according to some embodiments of the present invention;

FIG. **63**A is a block diagram of an exemplary power supply module in an LED tube lamp according to some embodiments of the present invention;

FIG. **63**B is a block diagram of an exemplary power supply module in an LED tube lamp according to some embodiments of the present invention;

FIG. **63**C is a schematic diagram of an auxiliary power module according to an embodiment of the present invention;

FIG. **64**A is a block diagram of an exemplary power supply module in an LED tube lamp according to some embodiments of the present invention;

FIG. **64**B is a block diagram of an installation detection module according to some embodiments of the present invention;

FIG. **64**C is a schematic detection pulse generating module according to some embodiments of the present invention;

FIG. **64**D is a schematic detection determining circuit according to some embodiments of the present invention;

FIG. **64**E is a schematic detection result latching circuit according to some embodiments of the present invention; and

FIG. **64**F is a schematic switch circuit according to some embodiments of the present invention.

DETAILED DESCRIPTION

The present disclosure provides a novel LED tube lamp. The present disclosure will now be described in the following embodiments with reference to the drawings. The following descriptions of various embodiments of this invention are presented herein for purpose of illustration and giving examples only. It is not intended to be exhaustive or to be limited to the precise form disclosed. These example embodiments are just that—examples—and many implementations and variations are possible that do not require the details provided herein. It should also be emphasized that the disclosure provides details of alternative examples, but such listing of alternatives is not exhaustive. Furthermore, any consistency of detail between various examples should not be interpreted as requiring such detail—it is impracticable to list every possible variation for every feature described herein. The language of the claims should be referenced in determining the requirements of the invention.

In the drawings, the size and relative sizes of components may be exaggerated for clarity. Like numbers refer to like elements throughout.

The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the invention. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items and may be abbreviated as "/".

It will be understood that, although the terms first, second, third etc. may be used herein to describe various elements, components, regions, layers, or steps, these elements, components, regions, layers, and/or steps should not be limited by these terms. Unless the context indicates otherwise, these terms are only used to distinguish one element, component, region, layer, or step from another element, component, region, or step, for example as a naming convention. Thus, a first element, component, region, layer, or step discussed below in one section of the specification could be termed a second element, component, region, layer, or step in another section of the specification or in the claims without departing from the teachings of the present invention. In addition, in certain cases, even if a term is not described using "first," "second," etc., in the specification, it may still be referred to as "first" or "second" in a claim in order to distinguish different claimed elements from each other.

It will be further understood that the terms "comprises" and/or "comprising," or "includes" and/or "including" when used in this specification, specify the presence of stated features, regions, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, regions, integers, steps, operations, elements, components, and/or groups thereof.

It will be understood that when an element is referred to as being "connected" or "coupled" to or "on" another element, it can be directly connected or coupled to or on the other element or intervening elements may be present. In contrast, when an element is referred to as being "directly connected" or "directly coupled" to another element, there are no intervening elements present. Other words used to describe the relationship between elements should be interpreted in a like fashion (e.g., "between" versus "directly between," "adjacent" versus "directly adjacent," etc.). However, the term "contact," as used herein refers to direct contact (i.e., touching) unless the context indicates otherwise.

Embodiments described herein will be described referring to plan views and/or cross-sectional views by way of ideal schematic views. Accordingly, the exemplary views may be modified depending on manufacturing technologies and/or tolerances. Therefore, the disclosed embodiments are not limited to those shown in the views, but include modifications in configuration formed on the basis of manufacturing processes. Therefore, regions exemplified in figures may have schematic properties, and shapes of regions shown in figures may exemplify specific shapes of regions of elements to which aspects of the invention are not limited.

Spatially relative terms, such as "beneath," "below," "lower," "above," "upper" and the like, may be used herein for ease of description to describe one element's or feature's relationship to another element(s) or feature(s) as illustrated in the figures. It will be understood that the spatially relative terms are intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. For example, if the device in the figures is turned over, elements described as "below" or "beneath" other elements or features would then be oriented "above" the other elements or features. Thus, the term "below" can encompass both an orientation of above and below. The device may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein interpreted accordingly.

Terms such as "same," "equal," "planar," or "coplanar," as used herein when referring to orientation, layout, location, shapes, sizes, amounts, or other measures do not necessarily mean an exactly identical orientation, layout, location, shape, size, amount, or other measure, but are intended to encompass nearly identical orientation, layout, location, shapes, sizes, amounts, or other measures within acceptable variations that may occur, for example, due to manufacturing processes. The term "substantially" may be used herein to reflect this meaning.

Terms such as "about" or "approximately" may reflect sizes, orientations, or layouts that vary only in a small relative manner, and/or in a way that does not significantly alter the operation, functionality, or structure of certain elements. For example, a range from "about 0.1 to about 1" may encompass a range such as a 0%-5% deviation around 0.1 and a 0% to 5% deviation around 1, especially if such deviation maintains the same effect as the listed range.

Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this disclosure belongs. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and/or the present application, and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

As used herein, items described as being "electrically connected" are configured such that an electrical signal can be passed from one item to the other. Therefore, a passive electrically conductive component (e.g., a wire, pad, internal electrical line, etc.) physically connected to a passive electrically insulative component (e.g., a prepreg layer of a printed circuit board, an electrically insulative adhesive connecting two devices, an electrically insulative underfill or mold layer, etc.) is not electrically connected to that component. Moreover, items that are "directly electrically connected," to each other are electrically connected through one or more passive elements, such as, for example, wires, pads, internal electrical lines, resistors, etc. As such, directly electrically connected components do not include components electrically connected through active elements, such as transistors or diodes.

Components described as thermally connected or in thermal communication are arranged such that heat will follow a path between the components to allow the heat to transfer from the first component to the second component. Simply because two components are part of the same device or board does not make them thermally connected. In general, components which are heat-conductive and directly connected to other heat-conductive or heat-generating components (or connected to those components through intermediate heat-conductive components or in such close proximity as to permit a substantial transfer of heat) will be described as thermally connected to those components, or in thermal communication with those components. On the contrary, two components with heat-insulative materials therebetween, which materials significantly prevent heat transfer between the two components, or only allow for incidental heat transfer, are not described as thermally connected or in thermal communication with each other. The terms "heat-conductive" or "thermally-conductive" do not apply to any material that provides incidental heat conduction, but are intended to refer to materials that are typically known as good heat conductors or known to have utility for transferring heat, or components having similar heat conducting properties as those materials.

Referring to FIGS. **1** and **2**, an LED tube lamp of one embodiment of the present invention includes a lamp tube **1**, an LED light strip **2** (shown in FIG. **2**) disposed inside the lamp tube **1**, and two end caps **3** respectively disposed at two ends of the lamp tube **1**. The lamp tube **1** may be made of plastic or glass. The sizes of the two end caps **3** may be same or different. Referring to FIG. **1**A, the size of one end cap may, in some embodiments, be about 30% to about 80% times the size of the other end cap.

In one embodiment, the lamp tube **1** is made of glass with strengthened or tempered structure to avoid being easily broken and incurring electrical shock, and to avoid the fast aging process. The glass made lamp tube **1** may be additionally strengthened or tempered by a chemical tempering method or a physical tempering method in various embodiments of the present invention.

An exemplary chemical tempering method is accomplished by exchanging the Na ions or K ions on the glass surface with other alkali metal ions and therefore changes composition of the glass surface. The sodium (Na) ions or potassium (K) ions and other alkali metal ions on the glass surface are exchanged to form an ion exchange layer on the glass surface. The glass is then under tension on the inside while under compression on the outside when cooled to room temperature, so as to achieve the purpose of increased strength. The chemical tempering method includes but is not limited to the following glass tempering methods: high temperature type ion exchange method, the low temperature type ion exchange method, dealkalization, surface crystallization, and/or sodium silicate strengthening methods, further explained as follows.

An exemplary embodiment of the high temperature type ion exchange method includes the following steps: Inserting glass containing sodium oxide (Na_2O) or potassium oxide (K_2O) in the temperature range of the softening point and glass transition point into molten salt of lithium, so that the Na ions in the glass are exchanged for Li ions in the molten salt. Later, the glass is then cooled to room temperature, since the surface layer containing Li ions has a different expansion coefficient with respect to the inner layer containing Na ions or K ions, thus the surface produces residual stress and is reinforced. Meanwhile, the glass containing Al_2O_3, TiO_2 and other components, by performing ion exchange, can produce glass crystals having an extremely low coefficient of expansion. The crystallized glass surface after cooling produces a significant amount of pressure, up to 700 MPa, which can enhance the strength of glass.

An exemplary embodiment of the low-temperature ion exchange method includes the following steps: First, a monovalent cation (e.g., K ions) undergoes ion exchange with the alkali ions (e.g. Na ion) on the surface layer at a temperature range that is lower than the strain point temperature, so as to allow the K ions to penetrate the surface. For example, for manufacturing a Na_2O+CaO+SiO_2 system glass, the glass can be impregnated for ten hours at more than four hundred degrees in the molten salt. The low temperature ion exchange method can easily obtain glass of higher strength, and the processing method is simple, does not damage the transparent nature of the glass surface, and does not undergo shape distortion.

An exemplary embodiment of dealkalization includes treating glass using platinum (Pt) catalyst along with sulfurous acid gas and water in a high temperature atmosphere. The Na+ ions are migrated out and bleed from the glass surface to be reacted with the Pt catalyst, so that the surface layer becomes a SiO_2 enriched layer, which results in a low expansion glass and produces compressive stress upon cooling.

The surface crystallization method and the high temperature type ion exchange method are different, but only the surface layer is treated by heat treatment to form low expansion coefficient microcrystals on the glass surface, thus reinforcing the glass.

An exemplary embodiment of the sodium silicate glass strengthening method is a tempering method using sodium silicate (water glass) in water solution at 100 degrees Celsius and several atmospheres of pressure treatment, where a stronger/higher strength glass surface that is harder to scratch is thereby produced.

An exemplary embodiment of the physical tempering method includes but is not limited to applying a coating to or changing the structure of an object such as to strengthen the easily broken position. The applied coating can be, for example, a ceramic coating, an acrylic coating, or a glass coating depending on the material used. The coating can be performed in a liquid phase or gaseous phase.

The above glass tempering methods described including physical tempering methods and chemical tempering methods can be accomplished singly or combined together in any fashion.

Referring to FIG. **2** and FIG. **15**, a glass made lamp tube of an LED tube lamp according to one embodiment of the present invention has structure-strengthened end regions described as follows. The glass made lamp tube **1** includes a main body region **102**, two rear end regions **101** (or just end regions **101**) respectively formed at two ends of the main body region **102**, and end caps **3** that respectively sleeve the rear end regions **101**. The outer diameter of at least one of the rear end regions **101** is less than the outer diameter of the main body region **102**. In the embodiment of FIGS. **2** and **15**, the outer diameters of the two rear end regions **101** are less than the outer diameter of the main body region **102**. In addition, the surface of the rear end region **101** is in substantially parallel with the surface of the main body region **102** in a cross-sectional view. Specifically, the glass made lamp tube **1** is strengthened at both ends, such that the rear end regions **101** are formed to be strengthened structures. In certain embodiments, the rear end regions **101** with strengthened structure are respectively sleeved with the end caps **3**, and the outer diameters of the end caps **3** and the main body region **102** have little or no differences. For example, the end caps **3** may have the same or substantially the same outer diameters as that of the main body region **102** such that there is no gap between the end caps **3** and the main body region **102**. In this way, a supporting seat in a packing box for transportation of the LED tube lamp contacts not only the end caps **3** but also the lamp tube **1** and makes uniform the loadings on the entire LED tube lamp to avoid situations where only the end caps **3** are forced, therefore preventing breakage at the connecting portion between the end caps **3** and the rear end regions **101** due to stress concentration. The quality and the appearance of the product are therefore improved.

In one embodiment, the end caps **3** and the main body region **102** have substantially the same outer diameters. These diameters may have a tolerance for example within +/−0.2 millimeter (mm), or in some cases up to +/−1.0 millimeter (mm). Depending on the thickness of the end caps **3**, the difference between an outer diameter of the rear end regions **101** and an outer diameter of the main body region **102** can be about 1 mm to about 10 mm for typical product applications. In some embodiments, the difference between the outer diameter of the rear end regions **101** and the outer diameter of the main body region **102** can be about 2 mm to about 7 mm

Referring to FIG. **15**, the lamp tube **1** is further formed with a transition region **103** between the main body region **102** and the rear end regions **101**. In one embodiment, the transition region **103** is a curved region formed to have cambers at two ends to smoothly connect the main body region **102** and the rear end regions **101**, respectively. For example, the two ends of the transition region **103** may be arc-shaped in a cross-section view along the axial direction of the lamp tube **1**. Furthermore, one of the cambers connects the main body region **102** while the other one of the cambers connects the rear end region **101**. In some embodiments, the arc angle of the cambers is greater than 90 degrees while the outer surface of the rear end region **101** is a continuous surface in parallel with the outer surface of the main body region **102** when viewed from the cross-section along the axial direction of the lamp tube. In other embodiments, the transition region **103** can be without curve or arc in shape. In certain embodiments, the length of the transition region **103** along the axial direction of the lamp tube **1** is between about 1 mm to about 4 mm Upon experimentation, it was found that when the length of the transition region **103** along the axial direction of the lamp tube **1** is less than 1 mm, the strength of the transition region would be insufficient; when the length of the transition region **103** along the axial direction of the lamp tube **1** is more than 4 mm, the main body region **102** would be shorter and the desired illumination surface would be reduced, and the end caps **3** would be longer and the more materials for the end caps **3** would be needed.

Referring to FIG. **5** and FIG. **16**, in certain embodiments, the lamp tube **1** is made of glass, and has a rear end region **101**, a main body region **102**, and a transition region **103**. The transition region **103** has two arc-shaped cambers at both ends to form an S shape; one camber positioned near the main body region **102** is convex outwardly, while the other camber positioned near the rear end region **101** is concaved inwardly. Generally speaking, the radius of curvature, R**1**, of the camber/arc between the transition region **103** and the main body region **102** is smaller than the radius of curvature, R**2**, of the camber/arc between the transition region **103** and the rear end region **101**. The ratio R**1**:R**2** may range, for example, from about 1:1.5 to about 1:10, and in some embodiments is more effective from about 1:2.5 to about 1:5, and in some embodiments is even more effective from about 1:3 to about 1:4. In this way, the camber/arc of the transition region **103** positioned near the rear end region **101** is in compression at outer surfaces and in tension at inner surfaces, and the camber/arc of the transition region **103** positioned near the main body region **102** is in tension at outer surfaces and in compression at inner surfaces. Therefore, the goal of strengthening the transition region **103** of the lamp tube **1** is achieved.

Taking the standard specification for T**8** lamp as an example, the outer diameter of the rear end region **101** is configured between 20.9 mm to 23 mm An outer diameter of the rear end region **101** being less than 20.9 mm would be too small to fittingly insert the power supply into the lamp tube **1**. The outer diameter of the main body region **102** is in some embodiments configured to be between about 25 mm to about 28 mm An outer diameter of the main body region **102** being less than 25 mm would be inconvenient to strengthen the ends of the main body region **102** as far as the current manufacturing skills are concerned, while an outer diameter of the main body region **102** being greater than 28 mm is not compliant to the industrial standard.

Referring to FIGS. **3** and **4**, in one embodiment of the invention, each end cap **3** includes an electrically insulating tube **302**, a thermal conductive member **303** sleeving over the electrically insulating tube **302**, and two hollow conductive pins **301** disposed on the electrically insulating tube **302**. The thermal conductive member **303** can be a metal ring that is tubular in shape.

Referring FIG. **5**, in one embodiment, one end of the thermal conductive member **303** extends away from the electrically insulating tube **302** of the end cap **3** and towards one end of the lamp tube **1**, and is bonded and adhered to the end of the lamp tube **1** using a hot melt adhesive **6**. In this way, the end cap **3** by way of the thermal conductive member **303** extends to the transition region **103** of the lamp tube **1**. In one embodiment, the thermal conductive member **303** and the transition region **103** are closely connected such that the hot melt adhesive **6** would not overflow out of the end cap **3** and remain on the main body region **102** when using the hot melt adhesive **6** to join the thermal conductive member **303** and the lamp tube **1**. In addition, the electrically insulating tube **302** facing toward the lamp tube **1** does not have an end extending to the transition region **103**, and that there is a gap between the electrically insulating tube **302** and the transition region **103**. In one embodiment, the electrically insulating tube **302** is not limited to being made of plastic or ceramic, any material that is not a good electrical conductor can be used.

The hot melt adhesive **6** is a composite including a so-called commonly known as "welding mud powder", and in some embodiments includes one or more of phenolic resin **2127**#, shellac, rosin, calcium carbonate powder, zinc oxide, and ethanol. Rosin is a thickening agent with a feature of being dissolved in ethanol but not dissolved in water. In one embodiment, a hot melt adhesive **6** having rosin could be expanded to change its physical status to become solidified when being heated to high temperature in addition to the intrinsic viscosity. Therefore, the end cap **3** and the lamp tube **1** can be adhered closely by using the hot melt adhesive to accomplish automatic manufacture for the LED tube lamps. In one embodiment, the hot melt adhesive **6** may be expansive and flowing and finally solidified after cooling. In this embodiment, the volume of the hot melt adhesive **6** expands to about 1.3 times the original size when heated from room temperature to about 200 to 250 degrees Celsius. The hot melt adhesive **6** is not limited to the materials recited herein. Alternatively, a material for the hot melt adhesive **6** to be solidified immediately when heated to a predetermined temperature can be used. The hot melt adhesive **6** provided in each embodiments of the present invention is durable with respect to high temperature inside the end caps **3** due to the heat resulted from the power supply. Therefore, the lamp tube **1** and the end caps **3** could be secured to each other without decreasing the reliability of the LED tube lamp.

Furthermore, there is formed an accommodation space between the inner surface of the thermal conductive member **303** and the outer surface of the lamp tube **1** to accommodate the hot melt adhesive **6**, as indicated by the dotted line B in FIG. **5**. For example, the hot melt adhesive **6** can be filled into the accommodation space at a location where a first hypothetical plane (as indicated by the dotted line B in FIG. **5**) being perpendicular to the axial direction of the lamp tube **1** would pass through the thermal conductive member, the hot melt adhesive **6**, and the outer surface of the lamp tube **1**. The hot melt adhesive **6** may have a thickness, for example, of about 0.2 mm to about 0.5 mm In one embodiment, the hot melt adhesive **6** will be expansive to solidify in and connect with the lamp tube **1** and the end cap **3** to secure both. The transition region **103** brings a height difference between the rear end region **101** and the main body region **102** to avoid the hot melt adhesives **6** being overflowed onto the main body region **102**, and thereby saves manpower to remove the overflowed adhesive and increase the LED tube lamp productivity. The hot melt adhesive **6** is heated by receiving heat from the thermal conductive member **303** to which an electricity from an external heating equipment is applied, and then expands and finally solidifies after cooling, such that the end caps **3** are adhered to the lamp tube **1**.

Referring to FIG. **5**, in one embodiment, the electrically insulating tube **302** of the end cap **3** includes a first tubular part **302***a* and a second tubular part **302***b* connected along an axial direction of the lamp tube **1**. The outer diameter of the second tubular part **302***b* is less than the outer diameter of the first tubular part **302***a*. In some embodiments, the outer diameter difference between the first tubular part **302***a* and the second tubular part **302***b* is between about 0.15 mm and about 0.30 mm The thermal conductive member **303** sleeves over the outer circumferential surface of the second tubular part **302***b*. The outer surface of the thermal conductive member **303** is coplanar or substantially flush with respect to the outer circumferential surface of the first tubular part **302***a*. For example, the thermal conductive member **303** and the first tubular part **302***a* have substantially uniform exterior diameters from end to end. As a result, the entire end cap **3** and thus the entire LED tube lamp may be smooth with respect to the outer appearance and may have a substantially uniform tubular outer surface, such that the loading during transportation on the entire LED tube lamp is also uniform. In one embodiment, a ratio of the length of the thermal conductive member **303** along the axial direction of the end cap **3** to the axial length of the electrically insulating tube **302** ranges from about 1:2.5 to about 1:5.

In one embodiment, for the sake of securing adhesion between the end cap **3** and the lamp tube **1**, the second tubular part **302***b* is at least partially disposed around the lamp tube **1**, and the accommodation space further includes a space encompassed by the inner surface of the second tubular part **302***b* and the outer surface of the rear end region **101** of the lamp tube **1**. The hot melt adhesive **6** is at least partially filled in an overlapped region (shown by a dotted line "A" in FIG. **5**) between the inner surface of the second tubular part **302***b* and the outer surface of the rear end region **101** of the lamp tube **1**. For example, the hot melt adhesive **6** may be filled into the accommodation space at a location where a second hypothetical plane (shown by the dotted line A in FIG. **5**) being perpendicular to the axial direction of the lamp tube **1** would pass through the thermal conductive member **303**, the second tubular part **302***b*, the hot melt adhesive **6**, and the rear end region **101**.

The hot melt adhesive **6** is not required to completely fill the entire accommodation space as shown in FIG. **5**, especially where a gap is reserved or formed between the thermal conductive member **303** and the second tubular part **302***b*. For example, in some embodiments, the hot melt adhesive **6** can be only partially filled into the accommodation space. During manufacturing of the LED tube lamp, the amount of the hot melt adhesive **6** coated and applied between the thermal conductive member **303** and the rear end region **101** may be appropriately increased, such that in the subsequent heating process, the hot melt adhesive **6** can be caused to expand and flow in between the second tubular part **302***b* and the rear end region **101**, and thereby solidify after cooling to join the second tubular part **302***b* and the rear end region **101**.

During fabrication of the LED tube lamp, the rear end region **101** of the lamp tube **1** is inserted into one of the end caps **3**. In some embodiments, the axial length of the inserted portion of the rear end region **101** of the lamp tube **1** accounts for approximately one-third (⅓) to two-thirds (⅔) of the total axial length of the thermal conductive member **303**. One benefit is that, there will be sufficient creepage distance between the hollow conductive pins **301** and the thermal conductive member **303**, and thus it is not easy to form a short circuit leading to dangerous electric shock to individuals. On the other hand, the creepage distance between the hollow conductive pin **301** and the thermal conductive member **303** is increased due to the electrically insulating effect of the electrically insulating tube **302**, and thus a high voltage test is more likely to pass without causing electrical shocks to people.

Furthermore, the presence of the second tubular part **302***b* interposed between the hot melt adhesive **6** and the thermal conductive member **303** may reduce the heat from the thermal conductive member **303** to the hot melt adhesive **6**. To help prevent or minimize this problem, referring to FIG. **4** in one embodiment, the end of the second tubular part **302***b* facing the lamp tube **1** (i.e., away from the first tubular part **302***a*) is circumferentially provided with a plurality of notches **302***c*. These notches **302***c* help to increase the contact areas between the thermal conductive member **303** and the hot melt adhesive **6** and therefore provide rapid heat conduction from the thermal conductive member **303** to the hot melt adhesive **6** so as to accelerate the solidification of the hot melt adhesive **6**. Moreover, the hot melt adhesive **6** electrically insulates the thermal conductive member **303** and the lamp tube **1** so that a user would not be electrically shocked when he touches the thermal conductive member **303** connected to a broken lamp tube **1**.

The thermal conductive member **303** can be made of various heat conducting materials. The thermal conductive member **303** can be a metal sheet such as an aluminum alloy. The thermal conductive member **303** sleeves the second tubular part **302***b* and can be tubular or ring-shaped. The electrically insulating tube **302** may be made of electrically insulating material, but in some embodiments have low thermal conductivity so as to prevent the heat from reaching the power supply module located inside the end cap **3** and therefore negatively affecting performance of the power supply module. In one embodiment, the electrically insulating tube **302** is a plastic tube.

Alternatively, the thermal conductive member **303** may be formed by a plurality of metal plates circumferentially arranged on the tubular part **302***b* with either an equidistant space or a non-equidistant space.

The end cap **3** may be designed to have other kinds of structures or include other elements. Referring to FIG. **6**, the end cap **3** according to another embodiment further includes a magnetic metal member **9** within the electrically insulating tube **302** but excludes the thermal conductive member **3**. The magnetic metal member **9** is fixedly arranged on the inner circumferential surface of the electrically insulating tube **302** and therefore interposed between the electrically insulating tube **302** and the lamp tube **1** such that the magnetic metal member **9** is partially overlapped with the lamp tube **1** in the radial direction. In this embodiment, the whole magnetic metal member **9** is inside the electrically insulating tube **302**, and the hot melt adhesive **6** is coated on the inner surface of the magnetic metal member **9** (the surface of the magnetic metal tube member **9** facing the lamp tube **1**) and adhered to the outer peripheral surface of the lamp tube **1**. In some embodiments, the hot melt adhesive **6** covers the entire inner surface of the magnetic metal member **9** in order to increase the adhesion area and to improve the stability of the adhesion.

Referring to FIG. **7**, when manufacturing the LED tube lamp of this embodiment, the electrically insulating tube **302** is inserted in an external heating equipment which is in some embodiments an induction coil **11**, so that the induction coil **11** and the magnetic metal member **9** are disposed opposite (or adjacent) to one another along the radially extending direction of the electrically insulating tube **302**. The induction coil **11** is energized and forms an electromagnetic field, and the electromagnetic field induces the magnetic metal member **9** to create an electrical current and become heated. The heat from the magnetic metal member **9** is transferred to the hot melt adhesive **6** to make the hot melt adhesive **6** expansive and flowing and then solidified after cooling, and the bonding for the end cap **3** and the lamp tube **1** can be accomplished. The induction coil **11** may be made, for example, of red copper and composed of metal wires having width of, for example, about 5 mm to about 6 mm to be a circular coil with a diameter, for example, of about 30 mm to about 35 mm, which is a bit greater than the outer diameter of the end cap **3**. Since the end cap **3** and the lamp tube **1** may have the same outer diameters, the outer diameter may change depending on the outer diameter of the lamp tube **1**, and therefore the diameter of the induction coil **11** used can be changed depending on the type of the lamp tube **1** used. As examples, the outer diameters of the lamp tube for T**12**, T**10**, T**8**, T**5**, T**4**, and T**2** are 38.1 mm, 31.8 mm, 25.4 mm, 16 mm, 12.7 mm, and 6.4 mm, respectively.

Furthermore, the induction coil **11** may be provided with a power amplifying unit to increase the alternating current power to about 1 to 2 times the original. In some embodiments, it is better that the induction coil **11** and the electrically insulating tube **302** are coaxially aligned to make energy transfer more uniform. In some embodiments, a deviation value between the axes of the induction coil **11** and the electrically insulating tube **302** is not greater than about 0.05 mm. When the bonding process is complete, the end cap **3** and the lamp tube **1** are moved away from the induction coil. Then, the hot melt adhesive **6** absorbs the energy to be expansive and flowing and solidified after cooling. In one embodiment, the magnetic metal member **9** can be heated to a temperature of about 250 to about 300 degrees Celsius; the hot melt adhesive **6** can be heated to a temperature of about 200 to about 250 degrees Celsius. The material of the hot melt adhesive is not limited here, and a material of allowing the hot melt adhesive to immediately solidify when absorb heat energy can also be used.

In one embodiment, the induction coil **11** may be fixed in position to allow the end cap **3** and the lamp tube **1** to be moved into the induction coil **11** such that the hot melt adhesive **6** is heated to expand and flow and then solidify after cooling when the end cap **3** is again moved away from the induction coil **11**. Alternatively, the end cap **3** and the lamp tube **1** may be fixed in position to allow the induction coil **11** to be moved to encompass the end cap **3** such that the hot melt adhesive **6** is heated to expand and flow and then solidify after cooling when the induction coil **11** is again moved away from the end cap **3**. In one embodiment, the external heating equipment for heating the magnetic metal member **9** is provided with a plurality of devices the same as the induction coils **11**, and the external heating equipment moves relative to the end cap **3** and the lamp tube **1** during the heating process. In this way, the external heating equipment moves away from the end cap **3** when the heating process is completed. However, the length of the lamp tube **1** is far greater than the length of the end cap **3** and may be up to above 240 cm in some special appliances, and this may cause bad connection between the end cap **3** and the lamp tube **1** during the process that the lamp tube **1** accompany with the end cap **3** to relatively enter or leave the induction coil **11** in the back and for the direction as mentioned above when a position error exists.

Referring to FIG. **44**, an external heating equipment **110** having a plurality sets of upper and lower semicircular fixtures lla is provided to achieve same heating effect as that brought by the induction coils **11**. In this way, the above-mentioned damage risk due to the relative movement in back-and-forth direction can be reduced. The upper and lower semicircular fixtures **11***a* each has a semicircular coil made by winding a metal wire of, for example, about 5 mm to about 6 mm wide. The combination of the upper and lower semicircular fixtures form a ring with a diameter, for example, of about 30 mm to about 35 mm, and the inside semicircular coils form a closed loop to become the induction coil **11** as mentioned. In this embodiment, the end cap **3** and the lamp tube **1** do not relatively move in the back-and-forth manner, but roll into the notch of the lower semicircular fixture. Specifically, an end cap **3** accompanied with a lamp tube **1** initially roll on a production line, and then the end cap **3** rolls into the notch of a lower semicircular fixture, and then the upper and the lower semicircular fixtures are combined to form a closed loop, and the fixtures are detached when heating is completed. This method reduces the need for high position precision and yield problems in production.

Referring to FIG. **6**, the electrically insulating tube **302** is further divided into two parts, namely a first tubular part **302***d* and a second tubular part **302***e*, i.e. the remaining part. In order to provide better support of the magnetic metal member **9**, an inner diameter of the first tubular part **302***d* for supporting the magnetic metal member **9** is larger than the inner diameter of the second tubular part **302***e* which does not have the magnetic metal member **9**, and a stepped structure is formed at the connection of the first tubular part **302***d* and the second tubular part **302***e*. In this way, an end of the magnetic metal member **9** as viewed in an axial direction is abutted against the stepped structure such that the entire inner surface of the end cap is smooth and plain. Additionally, the magnetic metal member **9** may be of various shapes, e.g., a sheet-like or tubular-like structure being circumferentially arranged or the like, where the magnetic metal member **9** is coaxially arranged with the electrically insulating tube **302**.

Referring to FIGS. **8** and **9**, the electrically insulating tube may be further formed with a supporting portion **313** on the inner surface of the electrically insulating tube **302** to be extending inwardly such that the magnetic metal member **9** is axially abutted against the upper edge of the supporting portion **313**. In some embodiments, the thickness of the supporting portion **313** along the radial direction of the electrically insulating tube **302** is between 1 mm to 2 mm The electrically insulating tube **302** may be further formed with a protruding portion **310** on the inner surface of the electrically insulating tube **302** to be extending inwardly such that the magnetic metal member **9** is radially abutted against the side edge of the protruding portion **310** and that the outer surface of the magnetic metal member **9** and the inner surface of the electrically insulating tube **302** is spaced apart with a gap. The thickness of the protruding portion **310** along the radial direction of the electrically insulating tube **302** is less than the thickness of the supporting portion **313** along the radial direction of the electrically insulating tube **302** and in some embodiments be 0.2 mm to 1 mm in an embodiment.

Referring to FIG. **9**, the protruding portion **310** and the supporting portion are connected along the axial direction, and the magnetic metal member **9** is axially abutted against the upper edge of the supporting portion **313** while radially abutted against the side edge of the protruding portion **310** such that at least part of the protruding portion **310** intervenes between the magnetic metal member **9** and the electrically insulating tube **302**. The protruding portion **310** may be arranged along the circumferential direction of the electrically insulating tube **302** to have a circular configuration. Alternatively, the protruding portion **310** may be in the form of a plurality of bumps arranged on the inner surface of the electrically insulating tube **302**. The bumps may be equidistantly or non-equidistantly arranged along the inner circumferential surface of the electrically insulating tube **302** as long as the outer surface of the magnetic metal member **9** and the inner surface of the electrically insulating tube **302** are in a minimum contact and simultaneously hold the hot melt adhesive **6**. In other embodiments, an entirely metal made end cap **3** could be used with an insulator disposed under the hollow conductive pin to endure the high voltage.

Referring to FIG. **10**, in one embodiment, the magnetic metal member **9** can have one or more openings **91** that are circular. However, the openings **91** may instead be, for example, oval, square, star shaped, etc., as long as the contact area between the magnetic metal member **9** and the inner peripheral surface of the electrically insulating tube **302** can be reduced and the function of the magnetic metal member **9** to heat the hot melt adhesive **6** can be performed. In some embodiments, the openings **91** occupy about 10% to about 50% of the surface area of the magnetic metal member **9**. The opening **91** can be arranged circumferentially on the magnetic metal member **9** in an equidistantly spaced or non-equidistantly spaced manner.

Referring to FIG. **11**, in other embodiments, the magnetic metal member **9** has an indentation/embossment **93** on surface facing the electrically insulating tube **302**. The embossment is raised from the inner surface of the magnetic metal member **9**, while the indentation is depressed under the inner surface of the magnetic metal member **9**. The indentation/embossment reduces the contact area between the inner peripheral surface of the electrically insulating tube **302** and the outer surface of the magnetic metal member **9** while maintaining the function of melting and curing the hot melt adhesive **6**. In sum, the surface of the magnetic metal member **9** can be configured to have openings, indentations, or embossments or any combination thereof to achieve the goal of reducing the contact area between the inner peripheral surface of the electrically insulating tube **302** and the outer surface of the magnetic metal member **9**. At the same time, the firm adhesion between the magnetic metal member **9** and the lamp tube **1** should be secured to accomplish the heating and solidification of the hot melt adhesive **6**.

Referring to FIG. **12**, in one embodiment, the magnetic metal member **9** is a circular ring. Referring to FIG. **13**, in another embodiment, the magnetic metal member **9** is a non-circular ring such as but not limited to an oval ring. When the magnetic metal member **9** is an oval ring, the minor axis of the oval ring is slightly larger than the outer diameter of the end region of the lamp tube **1** such that the contact area of the inner peripheral surface of the electrically insulating tube **302** and the outer surface of the magnetic metal member **9** is reduced and the function of melting and curing the hot melt adhesive **6** still performs properly. For example, the inner surface of the electrically insulating tube **302** may be formed with supporting portion **313** and the magnetic metal member **9** in a non-circular ring shape is seated on the supporting portion **313**. Thus, the contact area of the outer surface of the magnetic metal member **9** and the inner surface of the electrically insulating tube **302** could be reduced while that the function of solidifying the hot melt adhesive **6** could be performed. In other embodiments, the magnetic metal member **9** can be disposed on the outer surface of the end cap **3** to replace the thermal conductive member **303** as shown in FIG. **5** and to perform the function of heating and solidifying the hot melt adhesive **6** via electromagnetic induction.

Referring to FIGS. **45** to **47**, in other embodiments, the magnetic metal member **9** may be omitted. Instead, in some embodiments, the hot melt adhesive **6** has a predetermined proportion of high permeability powders **65** having relative permeability ranging, for example, from about 102 to about 106. The powders can be used to replace the calcite powders originally included in the hot melt adhesive **6**, and in certain embodiments, a volume ratio of the high permeability powders **65** to the calcite powders may be about 1:3~1:1. In some embodiments, the material of the high permeability powders **65** is one of iron, nickel, cobalt, alloy thereof, or any combination thereof; the weight percentage of the high permeability powders **65** with respect to the hot melt adhesive is about 10% to about 50%; and/or the powders may have mean particle size of about 1 to about 30 micrometers. Such a hot melt adhesive **6** allows the end cap **3** and the lamp tube **1** to adhere together and be qualified in a destruction test, a torque test, and a bending test. Generally speaking, the bending test standard for the end cap of the LED tube lamp is greater than 5 newton-meters (Nt-m), while the torque test standard is greater than 1.5 newton-meters (Nt-m). In one embodiment, upon the ratio of the high permeability powders **65** to the hot melt adhesive **6** and the magnetic flux applied, the end cap **3** and the end of the lamp tube **1** secured by using the hot melt adhesive **6** are qualified in a torque test of 1.5 to 5 newton-meters (Nt-m) and a bending test of 5 to 10 newton-meters (Nt-m). The induction coil **11** is first switched on and allow the high permeability powders uniformly distributed in the hot melt adhesive **6** to be charged, and therefore allow the hot melt adhesive **6** to be heated to be expansive and flowing and then solidified after cooling. Thereby, the goal of adhering the end cap **3** onto the lamp tube **1** is achieved.

Referring to FIGS. **45** to **47**, the high permeability powders **65** may have different distribution manners in the hot melt adhesive **6**. As shown in FIG. **45**, the high permeability powders **65** have mean particle size (e.g., diameter) of about 1 to about 5 micrometers, and are distributed uniformly in the hot melt adhesive **6**. When such a hot melt adhesive **6** is coated on the inner surface of the end cap **3**, though the high permeability powders **65** cannot form a closed loop due to the uniform distribution, they can still be heated due to magnetic hysteresis in the electromagnetic field, so as to heat the hot melt adhesive **6**. As shown in FIG. **46**, the high permeability powders **65** have mean particle size of about 1 to about 5 micrometers, and are distributed randomly in the hot melt adhesive **6**. When such a hot melt adhesive **6** is coated on the inner surface of the end cap **3**, the high permeability powders **65** form a closed loop due to the random distribution; they can be heated due to magnetic hysteresis or the closed loop in the electromagnetic field, so as to heat the hot melt adhesive **6**. As shown in FIG. **47**, the high permeability powders **65** have mean particle size of about 5 to about 30 micrometers, and are distributed randomly in the hot melt adhesive **6**. When such a hot melt adhesive **6** is coated on the inner surface of the end cap **3**, the high permeability powders **65** form a closed loop due to the random distribution; they can be heated due to magnetic hysteresis or the closed loop in the electromagnetic field, so as to heat the hot melt adhesive **6**. Accordingly, depending on the adjustment of the particle size, the distribution density and the distribution manner of the high permeability powders **65**, and the electromagnetic flux applied to the end cap **3**, the heating temperature of the hot melt adhesive **6** can be controlled. In one embodiment, the hot melt adhesive **6** is flowing and solidified after cooling from a temperature of about 200 to about 250 degrees Celsius. In another embodiment, the hot melt adhesive **6** is immediately solidified at a temperature of about 200 to about 250 degrees Celsius.

Referring to FIGS. **14** and **39**, in one embodiment, an end cap **3'** has a pillar **312** at one end, the top end of the pillar **312** is provided with an opening having a groove **314** of, for example 0.1±1% mm depth at the periphery thereof for positioning a conductive lead **53** as shown in FIG. **39**. The conductive lead **53** passes through the opening on top of the pillar **312** and has its end bent to be disposed in the groove **314**. After that, a conductive metallic cap **311** covers the pillar **312** such that the conductive lead **53** is fixed between

the pillar **312** and the conductive metallic cap **311**. In some embodiments, the inner diameter of the conductive metallic cap **311** is 7.56±5% mm, the outer diameter of the pillar **312** is 7.23±5% mm, and the outer diameter of the conductive lead **53** is 0.5±1% mm Nevertheless, the mentioned sizes are not limited here once that the conductive metallic cap **311** closely covers the pillar **312** without using extra adhesives and therefore completes the electrical connection between the power supply **5** and the conductive metallic cap **311**.

Referring to FIGS. **2**, **3**, **12**, and **13**, in one embodiment, the end cap **3** may have openings **304** to dissipate heat generated by the power supply modules inside the end cap **3** so as to prevent a high temperature condition inside the end cap **3** that might reduce reliability. In some embodiments, the openings are in a shape of an arc; especially in a shape of three arcs with different size. In one embodiment, the openings are in a shape of three arcs with gradually varying size. The openings on the end cap **3** can be in any one of the above-mentioned shape or any combination thereof.

In other embodiments, the end cap **3** is provided with a socket (not shown) for installing the power supply module.

Referring to FIG. **17**, in one embodiment, the lamp tube **1** further has a diffusion film **13** coated and bonded to the inner surface thereof so that the light outputted or emitted from the LED light sources **202** is diffused by the diffusion film **13** and then pass through the lamp tube **1**. The diffusion film **13** can be in form of various types, such as a coating onto the inner surface or outer wall of the lamp tube **1**, or a diffusion coating layer (not shown) coated at the surface of each LED light source **202**, or a separate membrane covering the LED light source **202**.

Referring again to FIG. **17**, in one embodiment, when the diffusion film **13** is in the form of a sheet, it covers but is not in contact with the LED light sources **202**. The diffusion film **13** in the form of a sheet is usually called an optical diffusion sheet or board, usually a composite made of mixing diffusion particles into polystyrene (PS), polymethyl methacrylate (PMMA), polyethylene terephthalate (PET), and/or polycarbonate (PC), and/or any combination thereof. The light passing through such composite is diffused to expand in a wide range of space such as a light emitted from a plane source, and therefore makes the brightness of the LED tube lamp uniform.

In alternative embodiments, the diffusion film **13** is in form of an optical diffusion coating, which is composed of any one of calcium carbonate, halogen calcium phosphate and aluminum oxide, or any combination thereof. When the optical diffusion coating is made from a calcium carbonate with suitable solution, an excellent light diffusion effect and transmittance to exceed 90% can be obtained. Furthermore, the diffusion film **13** in form of an optical diffusion coating may be applied to an outer surface of the rear end region **101** having the hot melt adhesive **6** to produce increased friction resistance between the end cap **3** and the rear end region **101**. Compared with an example without any optical diffusion coating, the rear end region **101** having the diffusion film **13** is beneficial, for example for preventing accidental detachment of the end cap **3** from the lamp tube **1**.

In one embodiment, the composition of the diffusion film **13** in form of the optical diffusion coating includes calcium carbonate, strontium phosphate (e.g., CMS-5000, white powder), thickener, and a ceramic activated carbon (e.g., ceramic activated carbon SW—C, which is a colorless liquid). Specifically, in one example, such an optical diffusion coating on the inner circumferential surface of the glass tube has an average thickness ranging between about 20 and about 30 μm. A light transmittance of the diffusion film **13** using this optical diffusion coating is about 90%. Generally speaking, the light transmittance of the diffusion film **13** ranges from 85% to 96%. In addition, this diffusion film **13** can also provide electrical isolation for reducing risk of electric shock to a user upon breakage of the lamp tube **1**. Furthermore, the diffusion film **13** provides an improved illumination distribution uniformity of the light outputted by the LED light sources **202** such that the light can illuminate the back of the light sources **202** and the side edges of the bendable circuit sheet so as to avoid the formation of dark regions inside the lamp tube **1** and improve the illumination comfort. In another possible embodiment, the light transmittance of the diffusion film can be 92% to 94% while the thickness ranges from about 200 to about 300 μm.

In another embodiment, the optical diffusion coating can also be made of a mixture including a calcium carbonate-based substance, some reflective substances like strontium phosphate or barium sulfate, a thickening agent, ceramic activated carbon, and deionized water. The mixture is coated on the inner circumferential surface of the glass tube and has an average thickness ranging between about 20 and about 30 μm. In view of the diffusion phenomena in microscopic terms, light is reflected by particles. The particle size of the reflective substance such as strontium phosphate or barium sulfate will be much larger than the particle size of the calcium carbonate. Therefore, adding a small amount of reflective substance in the optical diffusion coating can effectively increase the diffusion effect of light.

In other embodiments, halogen calcium phosphate or aluminum oxide can also serve as the main material for forming the diffusion film **13**. The particle size of the calcium carbonate is, for example, about 2 to 4 μm, while the particle size of the halogen calcium phosphate and aluminum oxide are about 4 to 6 μm and 1 to 2 μm, respectively. When the light transmittance is required to be 85% to 92%, the average thickness for the optical diffusion coating mainly having the calcium carbonate may be about 20 to about 30 μm, while the average thickness for the optical diffusion coating mainly having the halogen calcium phosphate may be about 25 to about 35 μm, and/or the average thickness for the optical diffusion coating mainly having the aluminum oxide may be about 10 to about 15 μm. However, when the required light transmittance is up to 92% and even higher, the optical diffusion coating mainly having the calcium carbonate, the halogen calcium phosphate, or the aluminum oxide should be even thinner.

The main material and the corresponding thickness of the optical diffusion coating can be decided according to the place for which the lamp tube **1** is used and the light transmittance required. It is noted that the higher the light transmittance of the diffusion film is required, the more apparent the grainy visual of the light sources is.

Referring to FIG. **17**, the inner circumferential surface of the lamp tube **1** may also be provided or bonded with a reflective film **12**. The reflective film **12** is provided around the LED light sources **202**, and occupies a portion of an area of the inner circumferential surface of the lamp tube **1** arranged along the circumferential direction thereof. As shown in FIG. **17**, the reflective film **12** is disposed at two sides of the LED light strip **2** extending along a circumferential direction of the lamp tube **1**. The LED light strip **2** is basically in a middle position of the lamp tube **1** and between the two reflective films **12**. The reflective film **12**, when viewed by a person looking at the lamp tube from the side (in the X-direction shown in FIG. **17**), serves to block the LED light sources **202**, so that the person does not directly see the LED light sources **202**, thereby reducing the visual graininess effect. On the other hand, that the lights emitted from the LED light sources **202** are reflected by the reflective film **12** facilitates the divergence angle control of the LED tube lamp, so that more lights illuminate toward directions without the reflective film **12**, such that the LED tube lamp has higher energy efficiency when providing the same level of illumination performance.

Specifically, the reflection film **12** is provided on the inner peripheral surface of the lamp tube **1**, and has an opening **12*a*** configured to accommodate the LED light strip **2**. The size of the opening **12*a*** is the same or slightly larger than the size of the LED light strip **2**. During assembly, the LED light sources **202** are mounted on the LED light strip **2** (a bendable circuit sheet) provided on the inner surface of the lamp tube **1**, and then the reflective film **12** is adhered to the inner surface of the lamp tube **1**, so that the opening **12*a*** of the reflective film **12** correspondingly matches the LED light strip **2** in a one-to-one relationship, and the LED light strip **2** is exposed to the outside of the reflective film **12**.

In one embodiment, the reflectance of the reflective film **12** is generally at least greater than 85%, in some embodiments greater than 90%, and in some embodiments greater than 95%, to be most effective. In one embodiment, the reflective film **12** extends circumferentially along the length of the lamp tube **1** occupying about 30% to 50% of the inner surface area of the lamp tube **1**. In other words, a ratio of a circumferential length of the reflective film **12** along the inner circumferential surface of the lamp tube **1** to a circumferential length of the lamp tube **1** is about 0.3 to 0.5. In the illustrated embodiment of FIG. **17**, the reflective film **12** is disposed substantially in the middle along a circumferential direction of the lamp tube **1**, so that the two distinct portions or sections of the reflective film **12** disposed on the two sides of the LED light strip **2** are substantially equal in area. The reflective film **12** may be made of PET with some reflective materials such as strontium phosphate or barium sulfate or any combination thereof, with a thickness between about 140 μm and about 350 μm or between about 150 μm and about 220 μm for a more preferred effect in some embodiments. As shown in FIG. **18**, in other embodiments, the reflective film **12** may be provided along the circumferential direction of the lamp tube **1** on only one side of the LED light strip **2** while occupying the same percentage of the inner surface area of the lamp tube **1** (e.g., 15% to 25% for the one side). Alternatively, as shown in FIGS. **19** and **20**, the reflective film **12** may be provided without any opening, and the reflective film **12** is directly adhered or mounted to the inner surface of the lamp tube **1** and followed by mounting or fixing the LED light strip **2** on the reflective film **12** such that the reflective film **12** positioned on one side or two sides of the LED light strip **2**.

In the above mentioned embodiments, various types of the reflective film **12** and the diffusion film **13** can be adopted to accomplish optical effects including single reflection, single diffusion, and/or combined reflection-diffusion. For example, the lamp tube **1** may be provided with only the reflective film **12**, and no diffusion film **13** is disposed inside the lamp tube **1**, such as shown in FIGS. **19**, **20**, and **21**.

In other embodiments, the width of the LED light strip **2** (along the circumferential direction of the lamp tube) can be widened to occupy a circumference area of the inner circumferential surface of the lamp tube **1**. Since the LED light strip **2** has on its surface a circuit protective layer made of an ink which can reflect lights, the widen part of the LED light strip **2** functions like the reflective film **12** as mentioned above. In some embodiments, a ratio of the length of the

LED light strip **2** along the circumferential direction to the circumferential length of the lamp tube **1** is about 0.3 to 0.5. The light emitted from the light sources could be concentrated by the reflection of the widen part of the LED light strip **2**.

In other embodiments, the inner surface of the glass made lamp tube may be coated totally with the optical diffusion coating, or partially with the optical diffusion coating (where the reflective film **12** is coated have no optical diffusion coating). No matter in what coating manner, in some embodiments, it is more desirable that the optical diffusion coating be coated on the outer surface of the rear end region of the lamp tube **1** so as to firmly secure the end cap **3** with the lamp tube **1**.

In the present invention, the light emitted from the light sources may be processed with the abovementioned diffusion film, reflective film, other kinds of diffusion layer sheets, adhesive film, or any combination thereof.

Referring again to FIG. **2**, the LED tube lamp according to some embodiments of present invention also includes an adhesive sheet **4**, an insulation adhesive sheet **7**, and an optical adhesive sheet **8**. The LED light strip **2** is fixed by the adhesive sheet **4** to an inner circumferential surface of the lamp tube **1**. The adhesive sheet **4** may be but is not limited to a silicone adhesive. The adhesive sheet **4** may be in the form of several short pieces or a long piece. Various kinds of the adhesive sheet **4**, the insulation adhesive sheet **7**, and the optical adhesive sheet **8** can be used to constitute various embodiments of the present invention.

The insulation adhesive sheet **7** is coated on the surface of the LED light strip **2** that faces the LED light sources **202** so that the LED light strip **2** is not exposed and thus electrically insulated from the outside environment. In application of the insulation adhesive sheet **7**, a plurality of through holes **71** on the insulation adhesive sheet **7** are reserved to correspondingly accommodate the LED light sources **202** such that the LED light sources **202** are mounted in the through holes **71**. The material composition of the insulation adhesive sheet **7** may include, for example vinyl silicone, hydrogen polysiloxane and aluminum oxide. The insulation adhesive sheet **7** has a thickness, for example, ranging from about 100 μm to about 140 μm (micrometers). The insulation adhesive sheet **7** having a thickness less than 100 μm typically does not produce sufficient insulating effect, while the insulation adhesive sheet **7** having a thickness more than 140 μm may result in material waste.

The optical adhesive sheet **8**, which is a clear or transparent material, is applied or coated on the surface of the LED light source **202** in order to ensure optimal light transmittance. After being applied to the LED light sources **202**, the optical adhesive sheet **8** may have a granular, strip-like or sheet-like shape. The performance of the optical adhesive sheet **8** depends on its refractive index and thickness. The refractive index of the optical adhesive sheet **8** is in some embodiments between 1.22 and 1.6. In some embodiments, it is better for the optical adhesive sheet **8** to have a refractive index being a square root of the refractive index of the housing or casing of the LED light source **202**, or the square root of the refractive index of the housing or casing of the LED light source **202** plus or minus 15%, to contribute better light transmittance. The housing/casing of the LED light sources **202** is a structure to accommodate and carry the LED dies (or chips) such as a LED lead frame **202***b* as shown in FIG. **37**. The refractive index of the optical adhesive sheet **8** may range from 1.225 to 1.253. In some embodiments, the thickness of the optical adhesive sheet **8** may range from 1.1 mm to 1.3 mm The optical adhesive sheet **8** having a thickness less than 1.1 mm may not be able to cover the LED light sources **202**, while the optical adhesive sheet **8** having a thickness more than 1.3 mm may reduce light transmittance and increases material cost.

In some embodiments, in the process of assembling the LED light sources to the LED light strip, the optical adhesive sheet **8** is first applied on the LED light sources **202**; then the insulation adhesive sheet **7** is coated on one side of the LED light strip **2**; then the LED light sources **202** are fixed or mounted on the LED light strip **2**; the other side of the LED light strip **2** being opposite to the side of mounting the LED light sources **202** is bonded and affixed to the inner surface of the lamp tube **1** by the adhesive sheet **4**; finally, the end cap **3** is fixed to the end portion of the lamp tube **1**, and the LED light sources **202** and the power supply **5** are electrically connected by the LED light strip **2**. As shown in the embodiment of FIG. **22**, the bendable circuit sheet **2** passes the transition region **103** to be soldered or traditionally wire-bonded with the power supply **5**, and then the end cap **3** having the structure as shown in FIG. **3** or **4** or FIG. **6** is adhered to the strengthened transition region **103** via methods as shown in FIG. **5** or FIG. **7**, respectively to form a complete LED tube lamp.

In this embodiment, the LED light strip **2** is fixed by the adhesive sheet **4** to an inner circumferential surface of the lamp tube **1**, so as to increase the light illumination angle of the LED tube lamp and broaden the viewing angle to be greater than 330 degrees. By means of applying the insulation adhesive sheet **7** and the optical adhesive sheet **8**, electrical insulation of the entire light strip **2** is accomplished such that electrical shock would not occur even when the lamp tube **1** is broken and therefore safety could be improved.

Furthermore, the inner peripheral surface or the outer circumferential surface of the glass made lamp tube **1** may be covered or coated with an adhesive film (not shown) to isolate the inside from the outside of the glass made lamp tube **1** when the glass made lamp tube **1** is broken. In this embodiment, the adhesive film is coated on the inner peripheral surface of the lamp tube **1**. The material for the coated adhesive film includes, for example, methyl vinyl silicone oil, hydro silicone oil, xylene, and calcium carbonate, wherein xylene is used as an auxiliary material. The xylene will be volatilized and removed when the coated adhesive film on the inner surface of the lamp tube **1** solidifies or hardens. The xylene is mainly used to adjust the capability of adhesion and therefore to control the thickness of the coated adhesive film.

In one embodiment, the thickness of the coated adhesive film is preferably between about 100 and about 140 micrometers (μm). The adhesive film having a thickness being less than 100 micrometers may not have sufficient shatterproof capability for the glass tube, and the glass tube is thus prone to crack or shatter. The adhesive film having a thickness being larger than 140 micrometers may reduce the light transmittance and also increase material cost. The thickness of the coated adhesive film may be between about 10 and about 800 micrometers (μm) when the shatterproof capability and the light transmittance are not strictly demanded.

In one embodiment, the inner peripheral surface or the outer circumferential surface of the glass made lamp tube **1** is coated with an adhesive film such that the broken pieces are adhered to the adhesive film when the glass made lamp tube is broken. Therefore, the lamp tube **1** would not be penetrated to form a through hole connecting the inside and outside of the lamp tube **1** and thus prevents a user from touching any charged object inside the lamp tube **1** to avoid electrical shock. In addition, the adhesive film is able to diffuse light and allows the light to transmit such that the light uniformity and the light transmittance of the entire LED tube lamp increases. The adhesive film can be used in combination with the adhesive sheet **4**, the insulation adhesive sheet **7** and the optical adhesive sheet **8** to constitute various embodiments of the present invention. As the LED light strip **2** is configured to be a bendable circuit sheet, no coated adhesive film is thereby required.

Furthermore, the light strip **2** may be an elongated aluminum plate, FR 4 board, or a bendable circuit sheet. When the lamp tube **1** is made of glass, adopting a rigid aluminum plate or FR4 board would make a broken lamp tube, e.g., broken into two parts, remain a straight shape so that a user may be under a false impression that the LED tube lamp is still usable and fully functional, and it is easy for him to incur electric shock upon handling or installation of the LED tube lamp. Because of added flexibility and bendability of the flexible substrate for the LED light strip **2**, the problem faced by the aluminum plate, FR4 board, or 3-layered flexible board having inadequate flexibility and bendability, are thereby addressed. In certain embodiments, a bendable circuit sheet is adopted as the LED light strip **2** for that such a LED light strip **2** would not allow a ruptured or broken lamp tube to maintain a straight shape and therefore instantly inform the user of the disability of the LED tube lamp and avoid possibly incurred electrical shock. The following are further descriptions of the bendable circuit sheet used as the LED light strip **2**.

Referring to FIG. **23**, in one embodiment, the LED light strip **2** includes a bendable circuit sheet having a conductive wiring layer **2***a* and a dielectric layer **2***b* that are arranged in a stacked manner, wherein the wiring layer **2***a* and the dielectric layer **2***b* have same areas. The LED light source **202** is disposed on one surface of the wiring layer **2***a*, the dielectric layer **2***b* is disposed on the other surface of the wiring layer **2***a* that is away from the LED light sources **202**. The wiring layer **2***a* is electrically connected to the power supply **5** to carry direct current (DC) signals. Meanwhile, the surface of the dielectric layer **2***b* away from the wiring layer **2***a* is fixed to the inner circumferential surface of the lamp tube **1** by means of the adhesive sheet **4**. The wiring layer **2***a* can be a metal layer or a power supply layer including wires such as copper wires.

In another embodiment, the outer surface of the wiring layer **2***a* or the dielectric layer **2***b* may be covered with a circuit protective layer made of an ink with function of resisting soldering and increasing reflectivity. Alternatively, the dielectric layer can be omitted and the wiring layer can be directly bonded to the inner circumferential surface of the lamp tube, and the outer surface of the wiring layer **2***a* is coated with the circuit protective layer. Whether the wiring layer **2***a* has a one-layered, or two-layered structure, the circuit protective layer can be adopted. In some embodiments, the circuit protective layer is disposed only on one side/surface of the LED light strip **2**, such as the surface having the LED light source **202**. In some embodiments, the bendable circuit sheet is a one-layered structure made of just one wiring layer **2***a*, or a two-layered structure made of one wiring layer **2***a* and one dielectric layer **2***b*, and thus is more bendable or flexible to curl when compared with the three-layered flexible substrate (one dielectric layer sandwiched with two wiring layers). As a result, the bendable circuit sheet of the LED light strip **2** can be installed in a lamp tube with a customized shape or non-tubular shape, and fitly mounted to the inner surface of the lamp tube. The bendable circuit sheet closely mounted to the inner surface of the lamp tube is preferable in some cases. In addition, using fewer layers of the bendable circuit sheet improves the heat dissipation and lowers the material cost.

Nevertheless, the bendable circuit sheet is not limited to being one-layered or two-layered; in other embodiments, the bendable circuit sheet may include multiple layers of the wiring layers **2***a* and multiple layers of the dielectric layers **2***b*, in which the dielectric layers **2***b* and the wiring layers **2***a* are sequentially stacked in a staggered manner, respectively. These stacked layers are away from the surface of the outermost wiring layer **2***a* which has the LED light source **202** disposed thereon and is electrically connected to the power supply **5**. Moreover, the length of the bendable circuit sheet is greater than the length of the lamp tube.

Referring to FIG. **48**, in one embodiment, the LED light strip **2** includes a bendable circuit sheet having in sequence a first wiring layer **2***a*, a dielectric layer **2***b*, and a second wiring layer **2***c*. The thickness of the second wiring layer **2***c* is greater than that of the first wiring layer **2***a*, and the length of the LED light strip **2** is greater than that of the lamp tube **1**. The end region of the light strip **2** extending beyond the end portion of the lamp tube **1** without disposition of the light source **202** is formed with two separate through holes **203** and **204** to respectively electrically communicate the first wiring layer **2***a* and the second wiring layer **2***c*. The through holes **203** and **204** are not communicated to each other to avoid short.

In this way, the greater thickness of the second wiring layer **2***c* allows the second wiring layer **2***c* to support the first wiring layer **2***a* and the dielectric layer **2***b*, and meanwhile allow the LED light strip **2** to be mounted onto the inner circumferential surface without being liable to shift or deform, and thus the yield rate of product can be improved. In addition, the first wiring layer **2***a* and the second wiring layer **2***c* are in electrical communication such that the circuit layout of the first wiring layer **2***a* can be extended downward to the second wiring layer **2***c* to reach the circuit layout of the entire LED light strip **2**. Moreover, since the land for the circuit layout becomes two-layered, the area of each single layer and therefore the width of the LED light strip **2** can be reduced such that more LED light strips **2** can be put on a production line to increase productivity.

Furthermore, the first wiring layer **2***a* and the second wiring layer **2***c* of the end region of the LED light strip **2** that extends beyond the end portion of the lamp tube **1** without disposition of the light source **202** can be used to accomplish the circuit layout of a power supply module so that the power supply module can be directly disposed on the bendable circuit sheet of the LED light strip **2**.

Referring to FIG. **2**, in one embodiment, the LED light strip **2** has a plurality of LED light sources **202** mounted thereon, and the end cap **3** has a power supply **5** installed therein. The LED light sources **202** and the power supply **5** are electrically connected by the LED light strip **2**. The power supply **5** may be a single integrated unit (i.e., all of the power supply components are integrated into one module unit) installed in one end cap **3**. Alternatively, the power supply **5** may be divided into two separate units (i.e. the power supply components are divided into two parts) installed in two end caps **3**, respectively. When only one end of the lamp tube **1** is strengthened by a glass tempering process, it may be preferable that the power supply **5** is a single integrated unit and installed in the end cap **3** corresponding to the strengthened end of the lamp tube **1**.

The power supply **5** can be fabricated by various ways. For example, the power supply **5** may be an encapsulation body formed by injection molding a silica gel with high thermal conductivity such as being greater than 0.7 w/m·k. This kind of power supply has advantages of high electrical insulation, high heat dissipation, and regular shape to match other components in an assembly. Alternatively, the power supply **5** in the end caps may be a printed circuit board having components that are directly exposed or packaged by a heat shrink sleeve. The power supply **5** according to some embodiments of the present invention can be a single printed circuit board provided with a power supply module as shown in FIG. **24** or a single integrated unit as shown in FIG. **38**.

Referring to FIGS. **2** and **38**, in one embodiment of the present invention, the power supply **5** is provided with a male plug **51** at one end and a metal pin **52** at the other end, one end of the LED light strip **2** is correspondingly provided with a female plug **201**, and the end cap **3** is provided with a hollow conductive pin **301** to be connected with an outer electrical power source. Specifically, the male plug **51** is fittingly inserted into the female plug **201** of the LED light strip **2**, while the metal pins **52** are fittingly inserted into the hollow conductive pins **301** of the end cap **3**. The male plug **51** and the female plug **201** function as a connector between the power supply **5** and the LED light strip **2**. Upon insertion of the metal pin **52**, the hollow conductive pin **301** is punched with an external punching tool to slightly deform such that the metal pin **52** of the power supply **5** is secured and electrically connected to the hollow conductive pin **301**. Upon turning on the electrical power, the electrical current passes in sequence through the hollow conductive pin **301**, the metal pin **52**, the male plug **51**, and the female plug **201** to reach the LED light strip **2** and go to the LED light sources **202**. However, the power supply **5** of the present invention is not limited to the modular type as shown in FIG. **38**. The power supply **5** may be a printed circuit board provided with a power supply module and electrically connected to the LED light strip **2** via the abovementioned the male plug **51** and female plug **201** combination.

In another embodiment, a traditional wire bonding technique can be used instead of the male plug **51** and the female plug **201** for connecting any kind of the power supply **5** and the light strip **2**. Furthermore, the wires may be wrapped with an electrically insulating tube to protect a user from being electrically shocked.

In still another embodiment, the connection between the power supply **5** and the LED light strip **2** may be accomplished via tin soldering, rivet bonding, or welding. One way to secure the LED light strip **2** is to provide the adhesive sheet **4** at one side thereof and adhere the LED light strip **2** to the inner surface of the lamp tube **1** via the adhesive sheet **4**. Two ends of the LED light strip **2** can be either fixed to or detached from the inner surface of the lamp tube **1**.

In case that two ends of the LED light strip **2** are fixed to the inner surface of the lamp tube **1**, it may be preferable that the bendable circuit sheet of the LED light strip **2** is provided with the female plug **201** and the power supply is provided with the male plug **51** to accomplish the connection between the LED light strip **2** and the power supply **5**. In this case, the male plug **51** of the power supply **5** is inserted into the female plug **201** to establish electrical connection.

In case that two ends of the LED light strip **2** are detached from the inner surface of the lamp tube and that the LED light strip **2** is connected to the power supply **5** via wire-bonding, any movement in subsequent transportation is likely to cause the bonded wires to break. Therefore, an option for the connection between the light strip **2** and the power supply **5** could be soldering. Specifically, referring to FIG. **22**, the ends of the LED light strip **2** including the

bendable circuit sheet are arranged to pass over the strengthened transition region **103** and directly soldering bonded to an output terminal of the power supply **5** such that the product quality is improved without using wires. In this way, the female plug **201** and the male plug **51** respectively provided for the LED light strip **2** and the power supply **5** are no longer needed.

Referring to FIG. **24**, an output terminal of the printed circuit board of the power supply **5** may have soldering pads "a" provided with an amount of tin solder with a thickness sufficient to later form a solder joint. Correspondingly, the ends of the LED light strip **2** may have soldering pads "b". The soldering pads "a" on the output terminal of the printed circuit board of the power supply **5** are soldered to the soldering pads "b" on the LED light strip **2** via the tin solder on the soldering pads "a". The soldering pads "a" and the soldering pads "b" may be face to face during soldering such that the connection between the LED light strip **2** and the printed circuit board of the power supply **5** is the most firm. However, this kind of soldering typically includes that a thermo-compression head presses on the rear surface of the LED light strip **2** and heats the tin solder, i.e. the LED light strip **2** intervenes between the thermo-compression head and the tin solder, and therefore may easily cause reliability problems. Referring to FIG. **30**, a through hole may be formed in each of the soldering pads "b" on the LED light strip **2** to allow the soldering pads "b" overlay the soldering pads "b" without face-to-face and the thermo-compression head directly presses tin solders on the soldering pads "a" on surface of the printed circuit board of the power supply **5** when the soldering pads "a" and the soldering pads "b" are vertically aligned. This is an easy way to accomplish in practice.

Referring again to FIG. **24**, two ends of the LED light strip **2** detached from the inner surface of the lamp tube **1** are formed as freely extending portions **21**, while most of the LED light strip **2** is attached and secured to the inner surface of the lamp tube **1**. One of the freely extending portions **21** has the soldering pads "b" as mentioned above. Upon assembling of the LED tube lamp, the freely extending end portions **21** along with the soldered connection of the printed circuit board of the power supply **5** and the LED light strip **2** would be coiled, curled up or deformed to be fittingly accommodated inside the lamp tube **1**. When the bendable circuit sheet of the LED light strip **2** includes in sequence the first wiring layer **2***a*, the dielectric layer **2***b*, and the second wiring layer **2***c* as shown in FIG. **48**, the freely extending end portions **21** can be used to accomplish the connection between the first wiring layer **2***a* and the second wiring layer **2***c* and arrange the circuit layout of the power supply **5**.

In this embodiment, during the connection of the LED light strip **2** and the power supply **5**, the soldering pads "b" and the soldering pads "a" and the LED light sources **202** are on surfaces facing toward the same direction and the soldering pads "b" on the LED light strip **2** are each formed with a through hole "e" as shown in FIG. **30** such that the soldering pads "b" and the soldering pads "a" communicate with each other via the through holes "e". When the freely extending end portions **21** are deformed due to contraction or curling up, the soldered connection of the printed circuit board of the power supply **5** and the LED light strip **2** exerts a lateral tension on the power supply **5**. Furthermore, the soldered connection of the printed circuit board of the power supply **5** and the LED light strip **2** also exerts a downward tension on the power supply **5** when compared with the situation where the soldering pads "a" of the power supply **5** and the soldering pads "b" of the LED light strip **2** are face to face. This downward tension on the power supply **5** comes from the tin solders inside the through holes "e" and forms a stronger and more secure electrical connection between the LED light strip **2** and the power supply **5**.

Referring to FIG. **25**, in one embodiment, the soldering pads "b" of the LED light strip **2** are two separate pads to electrically connect the positive and negative electrodes of the bendable circuit sheet of the LED light strip **2**, respectively. The size of the soldering pads "b" may be, for example, about 3.5×2 mm2 The printed circuit board of the power supply **5** is correspondingly provided with soldering pads "a" having reserved tin solders, and the height of the tin solders suitable for subsequent automatic soldering bonding process is generally, for example, about 0.1 to 0.7 mm, in some preferable embodiments about 0.3 to about 0.5 mm, and in some even more preferable embodiments about 0.4 mm An electrically insulating through hole "c" may be formed between the two soldering pads "b" to isolate and prevent the two soldering pads from electrically short during soldering. Furthermore, an extra positioning opening "d" may also be provided behind the electrically insulating through hole "c" to allow an automatic soldering machine to quickly recognize the position of the soldering pads "b".

For the sake of achieving scalability and compatibility, the amount of the soldering pads "b" on each end of the LED light strip **2** may be more than one such as two, three, four, or more than four. When there is only one soldering pad "b" provided at each end of the LED light strip **2**, the two ends of the LED light strip **2** are electrically connected to the power supply **5** to form a loop, and various electrical components can be used. For example, a capacitance may be replaced by an inductance to perform current regulation. Referring to FIGS. **26** to **28**, when each end of the LED light strip **2** has three soldering pads, the third soldering pad can be grounded; when each end of the LED light strip **2** has four soldering pads, the fourth soldering pad can be used as a signal input terminal. Correspondingly, in some embodiments, the power supply **5** should have same amount of soldering pads "a" as that of the soldering pads "b" on the LED light strip **2**. In some embodiments, as long as electrical short between the soldering pads "b" can be prevented, the soldering pads "b" should be arranged according to the dimension of the actual area for disposition, for example, three soldering pads can be arranged in a row or two rows. In other embodiments, the amount of the soldering pads "b" on the bendable circuit sheet of the LED light strip **2** may be reduced by rearranging the circuits on the bendable circuit sheet of the LED light strip **2**. The lesser the amount of the soldering pads, the easier the fabrication process becomes. On the other hand, a greater number of soldering pads may improve and secure the electrical connection between the LED light strip **2** and the output terminal of the power supply **5**.

Referring to FIG. **30**, in another embodiment, the soldering pads "b" each is formed with a through hole "e" having a diameter generally of about 1 to 2 mm, in some preferred embodiments of about 1.2 to 1 8 mm, and in yet further preferred embodiments of about 1.5 mm The through hole "e" communicates the soldering pad "a" with the soldering pad "b" so that the tin solder on the soldering pads "a" passes through the through holes "e" and finally reach the soldering pads "b". A smaller through hole "e" would make it difficult for the tin solder to pass. The tin solder accumulates around the through holes "e" upon exiting the through holes "e" and condense to form a solder ball "g" with a larger diameter than that of the through holes "e" upon condensing. Such a solder ball "g" functions as a rivet to further increase the stability of the electrical connection between the soldering pads "a" on the power supply **5** and the soldering pads "b" on the LED light strip **2**.

Referring to FIGS. **31** to **32**, in other embodiments, when a distance from the through hole "e" to the side edge of the LED light strip **2** is less than 1 mm, the tin solder may pass through the through hole "e" to accumulate on the periphery of the through hole "e", and extra tin solder may spill over the soldering pads "b" to reflow along the side edge of the LED light strip **2** and join the tin solder on the soldering pads "a" of the power supply **5**. The tin solder then condenses to form a structure like a rivet to firmly secure the LED light strip **2** onto the printed circuit board of the power supply **5** such that reliable electric connection is achieved. Referring to FIGS. **33** and **34**, in another embodiment, the through hole "e" can be replaced by a notch "f" formed at the side edge of the soldering pads "b" for the tin solder to easily pass through the notch "f" and accumulate on the periphery of the notch "f" and to form a solder ball with a larger diameter than that of the notch "e" upon condensing. Such a solder ball may be formed like a C-shape rivet to enhance the secure capability of the electrically connecting structure.

The abovementioned through hole "e" or notch "f" might be formed in advance of soldering or formed by direct punching with a thermo-compression head, as shown in FIG. **40**, during soldering. The portion of the thermo-compression head for touching the tin solder may be flat, concave, or convex, or any combination thereof. The portion of the thermo-compression head for restraining the object to be soldered such as the LED light strip **2** may be strip-like or grid-like. The portion of the thermo-compression head for touching the tin solder does not completely cover the through hole "e" or the notch "f" to make sure that the tin solder is able to pass through the through hole "e" or the notch "f". The portion of the thermo-compression head being concave may function as a room to receive the solder ball.

Referring to FIG. **40**, a thermo-compression head **41** used for bonding the soldering pads "a" on the power supply **5** and the soldering pads "b" on the light strip **2** is mainly composed of four sections: a bonding plane **411**, a plurality of concave guiding tanks **412**, a plurality of concave molding tanks **413**, and a restraining plane **414**. The bonding plane **411** is a portion actually touching, pressing and heating the tin solder to perform soldering bonding. The bonding plane **411** may be flat, concave, convex or any combination thereof. The concave guiding tanks **412** are formed on the bonding plane **411** and opened near an edge of the bonding plane **411** to guide the heated and melted tin solder to flow into the through holes or notches formed on the soldering pads. For example, the guiding tanks **412** may function to guide and stop the melted tin solders. The concave molding tanks **413** are positioned beside the guiding tanks **412** and have a concave portion more depressed than that of the guiding tanks **412** such that the concave molding tanks **413** each form a housing to receive the solder ball. The restraining plane **414** is a portion next to the bonding plane **411** and formed with the concave molding tanks **413**. The restraining plane **414** is lower than the bonding plane **411** such that the restraining plane **414** firmly presses the LED light strip **2** on the printed circuit board of the power supply **5** while the bonding plane **411** presses against the soldering pads "b" during the soldering bonding. The restraining plane **414** may be strip-like or grid-like on surface. The difference of height of the bonding plane **411** and the restraining plane **414** is the thickness of the LED light strip **2**.

Referring to FIGS. **41**, **25**, and **40**, soldering pads corresponding to the soldering pads of the LED light strip are formed on the printed circuit board of the power supply **5** and tin solder is reserved on the soldering pads on the printed circuit board of the power supply **5** for subsequent soldering bonding performed by an automatic soldering bonding machine. The tin solder in some embodiments has a thickness of about 0.3 mm to about 0.5 mm such that the LED light strip **2** can be firmly soldered to the printed circuit board of the power supply **5**. As shown in FIG. **41**, in case of having height difference between two tin solders respectively reserved on two soldering pads on the printed circuit board of the power supply **5**, the higher one will be touched first and melted by the thermo-compression head **41** while the other one will be touched and start to melt until the higher one is melted to a height the same as the height of the other one. This usually incurs unsecured soldering bonding for the reserved tin solder with smaller height, and therefore affects the electrical connection between the LED light strip **2** and the printed circuit board of the power supply **5**. To alleviate this problem, in one embodiment, the present invention applies the kinetic equilibrium principal and installs a linkage mechanism on the thermo-compression head **41** to allow rotation of the thermo-compression head **41** during a soldering bonding such that the thermo-compression head **41** starts to heat and melt the two reserved tin solders only when the thermo-compression head **41** detects that the pressure on the two reserved tin solders are the same.

In the abovementioned embodiment, the thermo-compression head **41** is rotatable while the LED light strip **2** and the printed circuit board of the power supply **5** remain unmoved. Referring to FIG. **42**, in another embodiment, the thermo-compression head **41** is unmoved while the LED light strip is allowed to rotate. In this embodiment, the LED light strip **2** and the printed circuit board of the power supply **5** are loaded on a soldering vehicle **60** including a rotary platform **61**, a vehicle holder **62**, a rotating shaft **63**, and two elastic members **64**. The rotary platform **61** functions to carry the LED light strip **2** and the printed circuit board of the power supply **5**. The rotary platform **61** is movably mounted to the vehicle holder **62** via the rotating shaft **63** so that the rotary platform **61** is able to rotate with respect to the vehicle holder **62** while the vehicle holder **62** bears and holds the rotary platform **61**. The two elastic members **64** are disposed on two sides of the rotating shaft **63**, respectively, such that the rotary platform **61** in connection with the rotating shaft **63** always remains at the horizontal level when the rotary platform **61** is not loaded. In this embodiment, the elastic members **64** are springs for example, and the ends thereof are disposed corresponding to two sides of the rotating shaft **63** so as to function as two pivots on the vehicle holder **62**. As shown in FIG. **42**, when two tin solders reserved on the LED light strip **2** pressed by the thermo-compression head **41** are not at the same height level, the rotary platform **61** carrying the LED light strip **2** and the printed circuit board of the power supply **5** will be driven by the rotating shaft **63** to rotate until the thermo-compression head **41** detects the same pressure on the two reserved tin solders, and then starts a soldering bonding. Referring to FIG. **43**, when the rotary platform **61** rotates, the elastic members **64** at two sides of the rotating shaft **63** are compressed or pulled; and the driving force of the rotating shaft **63** releases and the rotary platform **61** returns to the original height level by the resilience of the elastic members **64** when the soldering bonding is completed.

In other embodiments, the rotary platform **61** may be designed to have mechanisms without using the rotating shaft **63** and the elastic members **64**. For example, the rotary platform **61** may be designed to have driving motors and active rotary mechanisms, and therefore the vehicle holder **62** is saved. Accordingly, other embodiments utilizing the kinetic equilibrium principle to drive the LED light strip **2** and the printed circuit board of the power supply **5** to move in order to complete the soldering bonding process are within the spirit of the present invention.

Referring to FIGS. **35** and **36**, in another embodiment, the LED light strip **2** and the power supply **5** may be connected by utilizing a circuit board assembly **25** instead of soldering bonding. The circuit board assembly **25** has a long circuit sheet **251** and a short circuit board **253** that are adhered to each other with the short circuit board **253** being adjacent to the side edge of the long circuit sheet **251**. The short circuit board **253** may be provided with power supply module **250** to form the power supply **5**. The short circuit board **253** is stiffer or more rigid than the long circuit sheet **251** to be able to support the power supply module **250**.

The long circuit sheet **251** may be the bendable circuit sheet of the LED light strip including a wiring layer **2*a*** as shown in FIG. **23**. The wiring layer **2*a*** of the long circuit sheet **251** and the power supply module **250** may be electrically connected in various manners depending on the demand in practice. As shown in FIG. **35**, the power supply module **250** and the long circuit sheet **251** having the wiring layer **2*a*** on surface are on the same side of the short circuit board **253** such that the power supply module **250** is directly connected to the long circuit sheet **251**. As shown in FIG. **36**, alternatively, the power supply module **250** and the long circuit sheet **251** including the wiring layer **2*a*** on surface are on opposite sides of the short circuit board **253** such that the power supply module **250** is directly connected to the short circuit board **253** and indirectly connected to the wiring layer **2*a*** of the LED light strip **2** by way of the short circuit board **253**.

As shown in FIG. **35**, in one embodiment, the long circuit sheet **251** and the short circuit board **253** are adhered together first, and the power supply module **250** is subsequently mounted on the wiring layer **2*a*** of the long circuit sheet **251** serving as the LED light strip **2**. The long circuit sheet **251** of the LED light strip **2** herein is not limited to include only one wiring layer **2*a*** and may further include another wiring layer such as the wiring layer **2*c*** shown in FIG. **48**. The light sources **202** are disposed on the wiring layer **2*a*** of the LED light strip **2** and electrically connected to the power supply **5** by way of the wiring layer **2*a***. As shown in FIG. **36**, in another embodiment, the long circuit sheet **251** of the LED light strip **2** may include a wiring layer **2*a*** and a dielectric layer **2*b***. The dielectric layer **2*b*** may be adhered to the short circuit board **253** first and the wiring layer **2*a*** is subsequently adhered to the dielectric layer **2*b*** and extends to the short circuit board **253**. All these embodiments are within the scope of applying the circuit board assembly concept of the present invention.

In the above-mentioned embodiments, the short circuit board **253** may have a length generally of about 15 mm to about 40 mm and in some preferable embodiments about 19 mm to about 36 mm, while the long circuit sheet **251** may have a length generally of about 800 mm to about 2800 mm and in some embodiments of about 1200 mm to about 2400 mm A ratio of the length of the short circuit board **253** to the length of the long circuit sheet **251** ranges from, for example, about 1:20 to about 1:200.

When the ends of the LED light strip **2** are not fixed on the inner surface of the lamp tube **1**, the connection between the LED light strip **2** and the power supply **5** via soldering bonding could not firmly support the power supply **5**, and it may be necessary to dispose the power supply **5** inside the end cap **3**. For example, a longer end cap to have enough space for receiving the power supply **5** would be needed. However, this will reduce the length of the lamp tube under the prerequisite that the total length of the LED tube lamp is fixed according to the product standard, and may therefore decrease the effective illuminating areas.

Referring to FIG. **39**, in one embodiment, a hard circuit board **22** made of aluminum (or an elongated aluminum plate) is used instead of the bendable circuit sheet, such that the ends or terminals of the hard circuit board **22** can be mounted at ends of the lamp tube **1**, and the power supply **5** is solder bonded to one of the ends or terminals of the hard circuit board **22** in a manner such that the printed circuit board of the power supply **5** is not parallel but may be perpendicular to the hard circuit board **22** to save space in the longitudinal direction used for the end cap. This solder bonding technique may be more convenient to accomplish and the effective illuminating areas of the LED tube lamp could also remain. Moreover, a conductive lead **53** for electrical connection with the end cap **3** could be formed directly on the power supply **5** without soldering other metal wires between the power supply **5** and the hollow conductive pin **301** as shown in FIG. **3**, and which facilitates the manufacturing of the LED tube lamp.

FIG. **49**A is a block diagram of a system including an LED tube lamp including a power supply module according to certain embodiments. Referring to FIG. **49**A, an AC power supply **508** is used to supply an AC supply signal. A lamp driving circuit **505** receives the AC supply signal from the AC power supply **508** and then converts it into an AC driving signal. An LED tube lamp **500** receives the AC driving signal from the lamp driving circuit **505** and is thus driven to emit light. In this embodiment, the LED tube lamp **500** is power-supplied at its both end caps respectively having two pins **501** and **502** and two pins **503** and **504**, which are coupled to the lamp driving circuit **505** to concurrently receive the AC driving signal to drive an LED unit (not shown) in the LED tube lamp **500** to emit light. However, in other embodiments, each end cap of the LED tube lamp could have only at least one pin for receiving the AC driving signal. That is, it is unnecessary to have two pins used in each end cap for the purpose of passing electricity through the both ends of the LED tube lamp **500**. In the present embodiment, the AC power supply **508** could be commercial electricity with 100-277 voltages in frequency of 50 Hz or 60 Hz. The lamp driving circuit **505** receives the AC supply signal from the AC power supply **508** and then converts it into the AC driving signal as an external driving signal. The lamp driving circuit **505** could be an electronic ballast and is used to convert the signal of commercial electricity into high-frequency and high-voltage AC driving signal. The common types of electronic ballast, such as instant-start electronic ballast, program-start electronic ballast, and rapid-start electronic ballast, can be applied to the LED tube lamp of the present invention. In some embodiments, the voltage of the AC driving signal is bigger than 300V and prefers 400-700V with frequency being higher than 10 kHz and preferring 20-50 kHz. FIG. **49**B is a block diagram of an LED lamp according to certain embodiments. Referring to FIG. **49**B, the power supply module of the LED lamp summarily includes a rectifying circuit **510**, a filtering circuit **520**, and a rectifying circuit **540**, and may comprise a portion of an LED lighting module **530**. The power supply module of the LED lamp could be used in the LED tube lamp **500** with a dual-end power supply in FIG. **49**A. The

rectifying circuit **510** is coupled to pins **501** and **502** to receive and then rectify an external driving signal conducted by pins **501** and **502**. The rectifying circuit **540** is coupled to pins **503** and **504** to receive and then rectify an external driving signal conducted by pins **503** and **504**. Therefore, the power supply module of the LED lamp may include two rectifying circuits **510** and **540** configured to output a rectified signal at output terminals **511** and **512**. The filtering circuit **520** is coupled to the output terminals **511** and **512** to receive and then filter the rectified signal, so as to output a filtered signal to filtering output terminals **521** and **522**. The LED lighting module **530** is coupled to the filtering output terminals **521** and **522** to receive the filtered signal and thereby to drive an LED unit (not shown) in the LED lighting module **530** to emit light.

FIG. **50**A is a schematic diagram of a rectifying circuit according to an embodiment of the present invention. Referring to FIG. **50**A, a rectifying circuit **610**, i.e. a bridge rectifier, includes four rectifying diodes **611**, **612**, **613**, and **614**, configured to full-wave rectify a received signal. The diode **611** has an anode connected to the output terminal **512**, and a cathode connected to the pin **502**. The diode **612** has an anode connected to the output terminal **512**, and a cathode connected to the pin **501**. The diode **613** has an anode connected to the pin **502**, and a cathode connected to the output terminal **511**. The diode **614** has an anode connected to the pin **501**, and a cathode connected to the output terminal **511**.

When the pins **501** and **502** receive an AC signal, the rectifying circuit **610** operates as follows. During the connected AC signal's positive half cycle, the AC signal is input through the pin **501**, the diode **614**, and the output terminal **511** in sequence, and later output through the output terminal **512**, the diode **611**, and the pin **502** in sequence. During the connected AC signal's negative half cycle, the AC signal is input through the pin **502**, the diode **613**, and the output terminal **511** in sequence, and later output through the output terminal **512**, the diode **612**, and the pin **501** in sequence. Therefore, during the connected AC signal's full cycle, the positive pole of the rectified signal produced by the rectifying circuit **610** keeps at the output terminal **511**, and the negative pole of the rectified signal remains at the output terminal **512**. Accordingly, the rectified signal produced or output by the rectifying circuit **610** is a full-wave rectified signal.

When the pins **501** and **502** are coupled to a DC power supply to receive a DC signal, the rectifying circuit **610** operates as follows. When the pin **501** is coupled to the positive end of the DC power supply and the pin **502** to the negative end of the DC power supply, the DC signal is input through the pin **501**, the diode **614**, and the output terminal **511** in sequence, and later output through the output terminal **512**, the diode **611**, and the pin **502** in sequence. When the pin **501** is coupled to the negative end of the DC power supply and the pin **502** to the positive end of the DC power supply, the DC signal is input through the pin **502**, the diode **613**, and the output terminal **511** in sequence, and later output through the output terminal **512**, the diode **612**, and the pin **501** in sequence. Therefore, no matter what the electrical polarity of the DC signal is between the pins **501** and **502**, the positive pole of the rectified signal produced by the rectifying circuit **610** keeps at the output terminal **511**, and the negative pole of the rectified signal remains at the output terminal **512**.

Therefore, the rectifying circuit **610** in this embodiment can output or produce a proper rectified signal regardless of whether the received input signal is an AC or DC signal.

FIG. **50**B is a schematic diagram of a rectifying circuit according to an embodiment of the present invention. Referring to FIG. **50**B, a rectifying circuit **710** includes two rectifying diodes **711** and **712** configured to half-wave rectify a received signal. The diode **711** has an anode connected to the pin **502**, and a cathode connected to the output terminal **511**. The diode **712** has an anode connected to the output terminal **511**, and a cathode connected to the pin **501**. The output terminal **512** may be omitted or grounded depending on applications in practice.

Next, exemplary operation(s) of the rectifying circuit **710** is described as follows.

In one embodiment, during a received AC signal's positive half cycle, the electrical potential at the pin **501** is higher than that at the pin **502**, so the diodes **711** and **712** are both in a cutoff state as being reverse-biased and make the rectifying circuit **710** stop outputting a rectified signal. During a received AC signal's negative half cycle, the electrical potential at the pin **501** is lower than that at the pin **502**, so the diodes **711** and **712** are both in a conducting state as being forward-biased and allow the AC signal to be input through the diode **711** and the output terminal **511**, and later to be output through the output terminal **512**, a ground terminal, or another end of the LED lamp which is not directly connected to the rectifying circuit **710**. Accordingly, the rectified signal produced or output by the rectifying circuit **710** is a half-wave rectified signal.

FIG. **50**C is a schematic diagram of a rectifying circuit according to an embodiment of the present invention. Referring to FIG. **50**C, a rectifying circuit **810** includes a rectifying unit **815** and a terminal adapter circuit **541**. In this embodiment, the rectifying unit **815** comprises a half-wave rectifier circuit including two diodes **811** and **812**, and is configured to half-wave rectification. The diode **811** has an anode connected to an output terminal **512**, and a cathode connected to a half-wave node **819**. The diode **812** has an anode connected to the half-wave node **819**, and a cathode connected to an output terminal **511**. The terminal adapter circuit **541** is coupled to the half-wave node **819** and the pins **501** and **502** to transmit a signal received at the pin **501** and/or the pin **502** to the half-wave node **819**. By means of the terminal adapting function of the terminal adapter circuit **541**, the rectifying circuit **810** allows of two input terminals (connected to the pins **501** and **502**) and two output terminals **511** and **512**.

Next, in certain embodiments, the rectifying circuit **810** operates as follows.

During a received AC signal's positive half cycle, the AC signal may be input through the pin **501** or **502**, the terminal adapter circuit **541**, the half-wave node **819**, the diode **812**, and the output terminal **511** in sequence, and later output through another end or circuit of the LED tube lamp. During a received AC signal's negative half cycle, the AC signal may be input through another end or circuit of the LED tube lamp, and later output through the output terminal **512**, the diode **811**, the half-wave node **819**, the terminal adapter circuit **541**, and the pin **501** or **502** in sequence.

It's worth noting that the terminal adapter circuit **541** may include resistor(s), capacitor(s), inductor(s), or any combination thereof, for performing at least one of functions of current/voltage limiting, types of protection, current/voltage regulation, and so forth. Descriptions of these functions are presented below.

In practice, the rectifying unit **815** and terminal adapter circuit **541** may be interchanged in position (as shown in FIG. **50**D) without altering the function of half-wave rectification. FIG. **50**D is a schematic diagram of a rectifying circuit according to an embodiment of the present invention. Referring to FIG. **50**D, the diode **811** has an anode connected to the pin **502** and the diode **812** has a cathode connected to the pin **501**. The cathode of diode **811** and the anode of diode **812** are connected to the half-wave node **819**. The terminal adapter circuit **541** is coupled to the half-wave node **819** and the output terminals **511** and **512**. During a received AC signal's positive half cycle, the AC signal may be input through another end or circuit of the LED tube lamp, and later output through the output terminal **512** or **511**, the terminal adapter circuit **541**, the half-wave node **819**, the diode **812**, and the pin **501** in sequence. During a received AC signal's negative half cycle, the AC signal may be input through the pin **502**, the diode **811**, the half-wave node **819**, the terminal adapter circuit **541**, and the output terminal **511** or **512** in sequence, and later output through another end or circuit of the LED tube lamp.

It is noticeable that the terminal adapter circuit **541** in embodiments shown in FIGS. **50**C and **50**D may be omitted and is therefore depicted by a dotted line. If the terminal adapter circuit **541** of FIG. **50**C is omitted, the pins **501** and **502** will be coupled to the half-wave node **819**. If the terminal adapter circuit **541** of FIG. **50**D is omitted, the output terminals **511** and **512** will be coupled to the half-wave node **819**.

The rectifying circuit as shown and explained in FIGS. **50**A-D can constitute or be the rectifying circuit **540** shown in FIG. **49**B, as having the pins **503** and **504** for conducting instead of the pins **501** and **502**.

Next, an explanation follows as to choosing embodiments and their combinations of the rectifying circuits **510** and **540**, with reference to FIG. **49**B.

The rectifying circuits **510** and **540** in embodiments shown in FIG. **49**B may each comprise any one of the rectifying circuits in FIGS. **50**A-D, and the terminal adapter circuit **541** in FIGS. **50**C-D may be omitted without altering the rectification function used by an LED tube lamp. When the rectifying circuits **510** and **540** each comprise a half-wave rectifier circuit described in FIGS. **50**B-D, during a received AC signal's positive or negative half cycle, the AC signal may be input to either the rectifying circuit **510** or the rectifying circuit **540**, and later output from another. Further, when the rectifying circuits **510** and **540** each comprise the rectifying circuit described in FIG. **50**C or **50**D, or when they comprise the rectifying circuits in FIGS. **50**C and **50**D individually, only one terminal adapter circuit **541** may be needed for functions of current/voltage limiting, types of protection, current/voltage regulation, etc. within the rectifying circuits **510** and **540**, and another terminal adapter circuit **541** within the rectifying circuit **510** or **540** can be ignored.

FIG. **51**A is a schematic diagram of the terminal adapter circuit according to an embodiment of the present invention. Referring to FIG. **51**A, a terminal adapter circuit **641** includes a capacitor **642** having an end connected to the pins **501** and **502**, and the other end thereof connected to the half-wave node **819**. The capacitor **642** has an equivalent impedance to an AC signal. This impedance increases as the frequency of the AC signal decreases, and decreases as the frequency increases. Therefore, the capacitor **642** in the terminal adapter circuit **641** in this embodiment works as a high-pass filter. Further, the terminal adapter circuit **641** is connected in series to an LED unit in the LED tube lamp, producing an equivalent impedance of the terminal adapter circuit **641** to perform a current/voltage limiting function on the LED unit, thereby preventing damaging of the LED unit from an excessive voltage across and/or current in the LED unit. In addition, selecting the capacitance value of the capacitor **642** according to the frequency of the AC signal can further enhance current/voltage regulation to the LED assembly.

It's worth noting that the terminal adapter circuit **641** may further include a capacitor **645** and/or capacitor **646**. The capacitor **645** has an end connected to the half-wave node **819**, and the other end connected to the pin **503**. The capacitor **646** has an end connected to the half-wave node **819**, and the other end connected to the pin **504**. For example, the half-wave node **819** may be a common connection node between the capacitors **645** and **646**. And the capacitor **642** acting as a current regulating capacitor is coupled to the common connection node and the pins **501** and **502**. In such a structure, the series-connected capacitors **642** and **645** exist between one of the pins **501** and **502** and the pin **503**, and/or the series-connected capacitors **642** and **646** exist between one of the pins **501** and **502** and the pin **504**. Through equivalent impedances of series-connected capacitors, voltages from the AC signal are divided. The divided voltage on the capacitors **645** and **646** prefers 100-500V, and 300-400V would be a preferred range. Referring to FIGS. **49**B and **51**A, according to the ratios between equivalent impedances of the series-connected capacitors, the voltages respectively across the capacitor **642** in the rectifying circuit **510**, the filtering circuit **520**, and the LED lighting module **530** can be controlled to make the current flowing through an LED module in the LED lighting module **530** being limited within a current rating, and then to protect/prevent the filtering circuit **520** and the LED lighting module **530** from being damaged by excessive voltages.

FIG. **51**B is a schematic diagram of the terminal adapter circuit according to an embodiment of the present invention. Referring to FIG. **51**B, a terminal adapter circuit **741** includes two capacitors **743** and **744**. The capacitor **743** has an end connected to the pin **501**, and the other end connected to the half-wave node **819**. The capacitor **744** has an end connected to the pin **502**, and the other end connected to the half-wave node **819**. Compared to the terminal adapter circuit **641** in FIG. **51**A, the terminal adapter circuit **741** has the capacitors **743** and **744** in place of the capacitor **642**. The capacitance values of the capacitors **743** and **744** may be the same as each other, or may differ from each other depending on the magnitudes of signals received by the pins **501** and **502**.

Also, the terminal adapter circuit **741** may further comprise a capacitor **745** and/or a capacitor **746**, and two of them are respectively connected to the pins **503** and **504**. Thus, each of the pins **501** and **502** and each of the pins **503** and **504** may be connected to a capacitor in series to achieve the functions of voltage division and other protections.

FIG. **51**C is a schematic diagram of the terminal adapter circuit according to an embodiment of the present invention. Referring to FIG. **51**C, a terminal adapter circuit **841** includes three capacitors **842**, **843**, and **844**. The capacitors **842** and **843** are connected in series between the pin **501** and the half-wave node **819**. The capacitors **842** and **844** are connected in series between the pin **502** and the half-wave node **819**. In such a circuit structure, if any one of the capacitors **842**, **843**, and **844** is shorted, there is still at least one capacitor (of the other two capacitors) between the pin **501** and the half-wave node **819** and between the pin **502** and the half-wave node **819**, which performs a current-limiting function. Therefore, in the event that a user accidentally gets an electric shock, this circuit structure will prevent an excessive current from flowing through and then seriously hurting the body of the user.

Likewise, the terminal adapter circuit **841** may further include a capacitor **845** and/or a capacitor **846**, and two of them are respectively connected to the pins **503** and **504**. Thus, each of the pins **501** and **502** and each of the pins **503** and **504** may be connected to a capacitor in series to achieve the functions of voltage division and other protections.

FIG. **51**D is a schematic diagram of the terminal adapter circuit according to an embodiment of the present invention. Referring to FIG. **51**D, a terminal adapter circuit **941** includes two fuses **947** and **948**. The fuse **947** has an end connected to the pin **501**, and the other end connected to the half-wave node **819**. The fuse **948** has an end connected to the pin **502**, and the other end connected to the half-wave node **819**. With the fuses **947** and **948**, when the current passing through each of the pins **501** and **502** exceeds the current threshold corresponding to the fuse **947** or **948**, the corresponding fuse **947** or **948** will accordingly melt and then break the circuit to achieve overcurrent protection.

Each of the embodiments for the terminal adapter circuits coupled to the pins **501** and **502** mentioned above can be used or included in the rectifying circuit **540** when the pins **503** and **504** and the pins **501** and **502** are interchanged in position.

Capacitance values of the capacitors in the embodiments of the terminal adapter circuits shown and described above, in some embodiments for example, are desirable to be in the range of about 100 pF-100 nF. Also, a capacitor used in the embodiments may be equivalently replaced by two or more capacitors connected in series or parallel. For example, each of the capacitors **642** and **842** may be replaced by two series-connected capacitors, one having a capacitance value chosen from the range of, for example, about 1.0 nF to 2.5 nF and being 1.5 nF in some embodiments, and another having a capacitance value chosen from the range of, such as about 1.5 nF to 3.0 nF and being 2.2 nF in some embodiments.

FIG. **43** is a circuit diagram of an LED lamp according to some embodiments of the present disclosure. In these embodiment(s) illustrated in FIG. **43**, a compatible circuit **140** (for the LED lamp to be compatible with e.g. an external AC power supply **508**, as described in this disclosure) is present which is electrically connected between the third pin B**1** (or **503** herein) and the fourth pin B**2** (or **504** herein), other than the first pin A**1** (or **501** herein) and the second pin A**2** (or **502** herein). The compatible circuit **140** includes or allows a first unidirectional current path I**1** and a second unidirectional current path **12**. The first unidirectional current path I**1** electrically connects to the LED (lighting) module **130**, to allow a current to flow from the LED (lighting) module **130** to one of the pins B**1** and B**2**. The LED (lighting) module **130** includes at least one LED **135**, an inductor L**1**, a diode D, and a transistor switch Q**1**, and is comparable to the LED lighting module **530** herein, wherein inductor L**1**, diode D, and transistor switch Q**1** are comparable to driving circuit **1930** herein. The second unidirectional current path **12** electrically connects to the filtering unit **120**, to allow a current to flow from one of the pins B**1** and B**2** to the filtering unit **120**. The filtering unit **120** includes two capacitors C**1** and C**2** and an inductor L**2**, and is comparable to the filtering unit **723** herein. Also, as shown in FIG. **43**, a rectifying unit **110** comprising diodes D**1**, D**2**, D**3**, and D**4** is coupled between the first and second pins A**1** and A**2** and the filtering unit **120**, and is comparable to the rectifying circuit **510** herein.

In these embodiments, the compatible circuit **140** includes diodes D**5** and D**6**, a capacitor C**3**, and fuses F**1** and F**2**. A cathode of the diode D**5** is electrically connected to the filtering unit **120**; an anode of the diode D**5** is electrically connected to both an end of capacitor C**3** and a cathode of the diode D**6**; and an anode of the diode D**6** is electrically connected to the filtering unit **120**. The other end of capacitor C**3** is electrically connected to the fuses F**1** and F**2**, which are electrically connected to pins B**1** and B**2** respectively. The capacitor C**3** can prevent or reduce the risk of a user accidentally touching electrically conducting part(s) of the LED lamp and thus getting electrically shocked when the user is installing the LED lamp (as to a lamp holder or socket). And the fuses F**1** and F**2** perform protection when an electrical current conducted through the LED lamp is excessive, to prevent an excessive current from damaging (electrical circuits in) the LED lamp.

If an AC signal is coupled/input across the pins A**1** and A**2** to provide a single-end power supply to an LED tube lamp, meaning the AC signal is provided across the pins A**1** and A**2** on one of the two ends of the lamp tube of the LED tube lamp, a current from the AC signal flows from one of the two pins A**1** and A**2** into the LED tube lamp, and then flows out of the LED tube lamp from the other of the two pins A**1** and A**2**.

On the other hand, if an AC signal is coupled/input across the two ends of the LED tube lamp, meaning the AC signal is coupled to one of pins A**1** and A**2** and one of pins B**1** and B**2** to provide a double-end power supply to the LED tube lamp, then a current from the AC signal flows from one of the two pins A**1** and A**2** (or one of the two pins B**1** and B**2**) into the LED tube lamp, and then flows out of the LED tube lamp from one of the two pins B**1** and B**2** (or one of the two pins A**1** and A**2**) at the other end of the LED tube lamp. Putting this differently, during the connected AC signal's positive half cycle, the current from the AC signal may flow through the first pin A**1** and the diode D**1** of the rectifying unit **110**, or through the second pin A**2** and the diode D**3** of the rectifying unit **110**, into the LED tube lamp, then flow through the filtering circuit **120** and the LED (lighting) module **130**, and then flow through the diode D**6** of the compatible circuit **140**, the capacitor C**3**, and finally through the fuse F**1** and the third pin B**1**, or fuse F**2** and the fourth pin B**2**, out of the LED tube lamp. And during the connected AC signal's negative half cycle, the current from the AC signal may flow through the third pin B**1** and the fuse F**1**, or through the fourth pin B**2** and the fuse F**2**, into the LED tube lamp, then flow through the capacitor C**3**, the diode D**5**, the filtering circuit **120** and the LED (lighting) module **130**, and finally through the diode D**2** of the rectifying unit **110** and the first pin A**1**, or the diode D**4** of the rectifying unit **110** and the second pin A**2**, out of the LED tube lamp.

FIG. **52**A is a block diagram of the filtering circuit according to an embodiment of the present invention. A rectifying circuit **510** is shown in FIG. **52**A for illustrating its connection with other components, without intending a filtering circuit **520** to include the rectifying circuit **510**. Referring to FIG. **52**A, the filtering circuit **520** includes a filtering unit **523** coupled to two rectifying output terminals **511** and **512** to receive and to filter out ripples of a rectified signal from the rectifying circuit **510**. Accordingly, the waveform of a filtered signal is smoother than that of the rectified signal. The filtering circuit **520** may further include another filtering unit **524** coupled between a rectifying circuit and a pin correspondingly, for example, between the rectifying circuit **510** and the pin **501**, the rectifying circuit **510** and the pin **502**, the rectifying circuit **540** and the pin **503**, and/or the rectifying circuit **540** and the pin **504**. The filtering unit **524** is used to filter a specific frequency, for example, to filter out a specific frequency of an external driving signal. In this embodiment, the filtering unit **524** is coupled between the rectifying circuit **510** and the pin **501**. The filtering circuit **520** may further include another filtering unit **525** coupled between one of the pins **501** and **502** and one of the diodes of the rectifying circuit **510**, or between one of the pins **503** and **504** and one of the diodes of the rectifying circuit **540** to reduce or filter out electromagnetic interference (EMI). In this embodiment, the filtering unit **525** is coupled between the pin **501** and one of diodes of the rectifying circuit **510** (not shown in FIG. **52**A). Since the filtering units **524** and **525** may be present or omitted depending on actual circumstances of their uses, they are depicted by a dotted line in FIG. **52**A.

FIG. **52**B is a schematic diagram of the filtering unit according to an embodiment of the present invention. Referring to FIG. **52**B, a filtering unit **623** includes a capacitor **625** having an end coupled to the output terminal **511** and a filtering output terminal **521** and the other end thereof coupled to the output terminal **512** and a filtering output terminal **522**, and is configured to low-pass filter a rectified signal from the output terminals **511** and **512**, so as to filter out high-frequency components of the rectified signal and thereby output a filtered signal at the filtering output terminals **521** and **522**.

FIG. **52**C is a schematic diagram of the filtering unit according to an embodiment of the present invention. Referring to FIG. **52**C, a filtering unit **723** includes a pi filter circuit including a capacitor **725**, an inductor **726**, and a capacitor **727**. As is well known, a pi filter circuit looks like the symbol **7**E in its shape or structure. The capacitor **725** has an end connected to the output terminal **511** and coupled to the filtering output terminal **521** through the inductor **726**, and has another end connected to the output terminal **512** and the filtering output terminal **522**. The inductor **726** is coupled between output terminal **511** and the filtering output terminal **521**. The capacitor **727** has an end connected to the filtering output terminal **521** and coupled to the output terminal **511** through the inductor **726**, and has another end connected to the output terminal **512** and the filtering output terminal **522**.

As seen between the output terminals **511** and **512** and the filtering output terminals **521** and **522**, the filtering unit **723** compared to the filtering unit **623** in FIG. **52**B additionally has an inductor **726** and a capacitor **727**, which perform the function of low-pass filtering like the capacitor **725** does. Therefore, the filtering unit **723** in this embodiment compared to the filtering unit **623** in FIG. **52**B has a better ability to filter out high-frequency components to output a filtered signal with a smoother waveform.

The inductance values of the inductor **726** in the embodiments mentioned above are chosen in the range of, for example in some embodiments, about 10 nH to 10 mH. And the capacitance values of the capacitors **625**, **725**, and **727** in the embodiments stated above are chosen in the range of, for example in some embodiments, about 100 pF to 1 uF.

FIG. **52**D is a schematic diagram of the filtering unit according to an embodiment of the present invention. Referring to FIG. **52**D, a filtering unit **824** includes a capacitor **825** and an inductor **828** connected in parallel. The capacitor **825** has an end coupled to the pin **501**, and the other end coupled to the output terminal **511**, and is configured to high-pass filter an external driving signal input at the pin **501** so as to filter out low-frequency components of the external driving signal. The inductor **828** has an end coupled to the pin **501** and the other end coupled to the output terminal **511**, and is configured to low-pass filter an external driving signal input at the pin **501** so as to filter out high-frequency components of the external driving signal. Therefore, the combination of the capacitor **825** and the inductor **828** works to present high impedance to one or more specific frequencies in an external driving signal. That is, the parallel-connected capacitor and inductor work to present a biggest equivalent impedance to a specific frequency in the external driving signal.

Through appropriately choosing a capacitance value for the capacitor **825** and an inductance value for the inductor **828**, a center frequency f on the high-impedance band may be set at a specific value given by

$$f = \frac{1}{2\pi\sqrt{LC}},$$

where L denotes inductance of the inductor **828** and C denotes capacitance of the capacitor **825**. The center frequency in some embodiments is in the range of about 20-30 kHz, and may be in some cases about 25 kHz. And an LED lamp with filtering unit **824** is able to be certified under safety standards, for a specific center frequency, as provided by Underwriters Laboratories (UL).

It's worth noting that the filtering unit **824** may further include a resistor **829** coupled between the pin **501** and the filtering output terminal **511**. In FIG. **52**D, the resistor **829** is connected in series to the parallel-connected capacitor **825** and inductor **828**. For example, the resistor **829** may be coupled between the pin **501** and the parallel-connected capacitor **825** and inductor **828**, or may be coupled between the output terminal **511** and the parallel-connected capacitor **825** and inductor **828**. In this embodiment, the resistor **829** is coupled between the pin **501** and the parallel-connected capacitor **825** and inductor **828**. Further, the resistor **829** is configured to adjust the quality factor (Q) of the LC circuit comprising the capacitor **825** and the inductor **828** to make the filtering unit **824** adapting to application environments with different quality factor requirements. Since the resistor **829** is an optional component, it is depicted in a dotted line in FIG. **52**D.

The capacitance values of the capacitor **825**, in some embodiments, are in the range of about 10 nF-2 uF. The inductance values of the inductor **828** are smaller than 2 mH in some embodiments, and may be in some cases smaller than 1 mH. The resistance values of the resistor **829** are bigger than 50 ohms in some embodiments, and may be in some cases bigger than 500 ohms.

In addition to the filtering circuits shown and described in the above embodiments, the traditional low-pass or band-pass filters can also be used as the filtering unit in the filtering circuit for the present invention.

FIG. **52**E is a schematic diagram of the filtering unit according to an embodiment of the present invention. Referring to FIG. **52**E, in this embodiment, a filtering unit **925** is disposed in the rectifying circuit **610** as shown in FIG. **50**A, and is configured for reducing the EMI (Electromagnetic interference) caused by the rectifying circuit **610** and/or other circuits. In this embodiment, the filtering unit **925** includes an EMI-reducing capacitor coupled between the pin **501** and the anode of the rectifying diode **614**, and also between the pin **502** and the anode of the rectifying diode **613** to reduce the EMI associated with the positive half cycle of the AC driving signal received at the pins **501** and **502**. The EMI-reducing capacitor of the filtering unit **925** is also coupled between the pin **501** and the cathode of the rectifying diode **612**, and between the pin **502** and the cathode of the rectifying diode **611** to reduce the EMI associated with the negative half cycle of the AC driving signal received at the pins **501** and **502**. In some embodiments, the rectifying circuit **610** includes a full-wave bridge rectifier circuit including four rectifying diodes **611**, **612**, **613**, and **614**. The full-wave bridge rectifier circuit has a first filtering node connecting the anode of the diode **613** and the cathode of the diode **611**, and a second filtering node connecting the anode of the diode **614** and the cathode of the diode **612**. And the EMI-reducing capacitor of the filtering unit **925** is coupled between the first filtering node and the second filtering node.

Similarly, with reference to FIGS. **50**C and **51**A-C, any capacitor in each of the circuits in FIGS. **51**A-C is coupled between the pins **501** and **502** (or the pins **503** and **504**) and any diode in FIG. **50**C, so any or each capacitor in FIGS. **51**A-C can work as an EMI-reducing capacitor to achieve the function of reducing EMI. For example, the rectifying circuit **510** in FIG. **49**B may include a half-wave rectifier circuit including two rectifying diodes and having a half-wave node respectively connecting an anode and a cathode of the two rectifying diodes, and any or each capacitor in FIGS. **51**A-C may be coupled between the half-wave node and at least one of the pins **501** and **502**. And the rectifying circuit **540** in FIG. **49**B may include a half-wave rectifier circuit including two rectifying diodes and having a half-wave node respectively connecting an anode and a cathode of the two rectifying diodes, and any or each capacitor in FIGS. **51**A-C may be coupled between the half-wave node and at least one of the pins **503** and **504**.

However, the filtering unit **925** coupled between the pins **501** and **502** is equal to make them short. Referring to FIGS. **51**A-C with the state of the filtering unit **925** making the pins **501** and **502** short, one of the capacitors **645**, **646**, **745**, **746**, **845**, and **846** in each corresponding embodiment can be ignored. In spite of the external AC signal being output from the pin **501** or **502**, the voltage-divided function still can be achieved after omitting one of the capacitors **645**, **646**, **745**, **746**, **845**, and **846** in each corresponding embodiment.

It's worth noting that the EMI-reducing capacitor in the embodiment of FIG. **52**E may also act as the capacitor **825** in the filtering unit **824** shown in FIG. **52**D, in combination with the inductor **828**, to achieve the functions of reducing EMI and presenting high impedance to an external driving signal at specific frequencies simultaneously. For example, when the rectifying circuit includes a full-wave bridge rectifier circuit, the capacitor **825** of the filtering unit **824** may be coupled between the first filtering node and the second filtering node of the full-wave bridge rectifier circuit. When the rectifying circuit includes a half-wave rectifier circuit, the capacitor **825** of the filtering unit **824** may be coupled between the half-wave node of the half-wave rectifier circuit and at least one of the pins **501** and **502**.

FIG. **53**A is a schematic diagram of an LED module according to an embodiment of the present invention. Referring to FIG. **53**S, LED module **630** has an anode connected to the filtering output terminal **521**, has a cathode connected to the filtering output terminal **522**, and comprises at least one LED unit **632**. When two or more LED units are included, they are connected in parallel. The anode of each LED unit **632** is connected to the anode of LED module **630** and thus output terminal **521**, and the cathode of each LED unit **632** is connected to the cathode of LED module **630** and thus output terminal **522**. Each LED unit **632** includes at least one LED **631**. When multiple LEDs **631** are included in an LED unit **632**, they are connected in series, with the anode of the first LED **631** connected to the anode of this LED unit **632**, and the cathode of the first LED **631** connected to the next or second LED **631**. And the anode of the last LED **631** in this LED unit **632** is connected to the cathode of a previous LED **631**, with the cathode of the last LED **631** connected to the cathode of this LED unit **632**.

It's worth noting that LED module **630** may produce a current detection signal S**531** reflecting a magnitude of current through LED module **630** and used for controlling or detecting on the LED module **630**.

FIG. **53**B is a schematic diagram of an LED module according to an embodiment of the present invention. Referring to FIG. **53**B, LED module **630** has an anode connected to the filtering output terminal **521**, has a cathode connected to the filtering output terminal **522**, and comprises at least two LED units **732**, with the anode of each LED unit **732** connected to the anode of LED module **630**, and the cathode of each LED unit **732** connected to the cathode of LED module **630**. Each LED unit **732** includes at least two LEDs **731** connected in the same way as described in FIG. **53**A. For example, the anode of the first LED **731** in an LED unit **732** is connected to the anode of this LED unit **732**, the cathode of the first LED **731** is connected to the anode of the next or second LED **731**, and the cathode of the last LED **731** is connected to the cathode of this LED unit **732**. Further, LED units **732** in an LED module **630** are connected to each other in this embodiment. All of the n-th LEDs **731** respectively of the LED units **732** are connected by every anode of every n-th LED **731** in the LED units **732**, and by every cathode of every n-th LED **731**, where n is a positive integer. In this way, the LEDs in LED module **630** in this embodiment are connected in the form of a mesh.

Compared to the embodiments of FIGS. **54**A-**54**G, LED driving module **530** of the above embodiments includes LED module **630**, but doesn't include a driving circuit for the LED module **630**.

Similarly, LED module **630** in this embodiment may produce a current detection signal S**531** reflecting a magnitude of current through LED module **630** and used for controlling or detecting on the LED module **630**.

In actual practice, the number of LEDs **731** included by an LED unit **732** is in some embodiments in the range of **15**-**25**, and is may be preferably in the range of **18**-**22**.

FIG. **53**C is a plan view of a circuit layout of the LED module according to an embodiment of the present invention. Referring to FIG. **53**C, in this embodiment LEDs **831** are connected in the same way as described in FIG. **53**B, and three LED units are assumed in LED module **630** and described as follows for illustration. A positive conductive line **834** and a negative conductive line **835** are to receive a driving signal, for supplying power to the LEDs **831**. For example, positive conductive line **834** may be coupled to the filtering output terminal **521** of the filtering circuit **520** described above, and negative conductive line **835** coupled to the filtering output terminal **522** of the filtering circuit **520**, to receive a filtered signal. For the convenience of illustration, all three of the n-th LEDs **831** respectively of the three LED units are grouped as an LED set **833** in FIG. **53**C.

Positive conductive line **834** connects the three first LEDs **831** respectively of the leftmost three LED units, at the anodes on the left sides of the three first LEDs **831** as shown in the leftmost LED set **833** of FIG. **53**C. Negative conductive line **835** connects the three last LEDs **831** respectively of the leftmost three LED units, at the cathodes on the right sides of the three last LEDs **831** as shown in the rightmost LED set **833** of FIG. **53**C. And of the three LED units, the cathodes of the three first LEDs **831**, the anodes of the three last LEDs **831**, and the anodes and cathodes of all the remaining LEDs **831** are connected by conductive lines or parts **839**.

For example, the anodes of the three LEDs **831** in the leftmost LED set **833** may be connected together by positive conductive line **834**, and their cathodes may be connected together by a leftmost conductive part **839**. The anodes of the three LEDs **831** in the second leftmost LED set **833** are also connected together by the leftmost conductive part **839**, whereas their cathodes are connected together by a second leftmost conductive part **839**. Since the cathodes of the three LEDs **831** in the leftmost LED set **833** and the anodes of the three LEDs **831** in the second leftmost LED set **833** are connected together by the same leftmost conductive part **839**, in each of the three LED units the cathode of the first LED **831** is connected to the anode of the next or second LED **831**, with the remaining LEDs **831** also being connected in the same way. Accordingly, all the LEDs **831** of the three LED units are connected to form the mesh as shown in FIG. **53**B.

It's worth noting that in this embodiment the length **836** of a portion of each conductive part **839** that immediately connects to the anode of an LED **831** is smaller than the length **837** of another portion of each conductive part **839** that immediately connects to the cathode of an LED **831**, making the area of the latter portion immediately connecting to the cathode larger than that of the former portion immediately connecting to the anode. The length **837** may be smaller than a length **838** of a portion of each conductive part **839** that immediately connects the cathode of an LED **831** and the anode of the next LED **831**, making the area of the portion of each conductive part **839** that immediately connects a cathode and an anode larger than the area of any other portion of each conductive part **839** that immediately connects to only a cathode or an anode of an LED **831**. Due to the length differences and area differences, this layout structure improves heat dissipation of the LEDs **831**.

In some embodiments, positive conductive line **834** includes a lengthwise portion **834***a*, and negative conductive line **835** includes a lengthwise portion **835***a*, which are conducive to making the LED module have a positive "+" connective portion and a negative "–" connective portion at each of the two ends of the LED module, as shown in FIG. **53**C. Such a layout structure allows for coupling any of other circuits of the power supply module of the LED lamp, including e.g. filtering circuit **520** and rectifying circuits **510** and **540**, to the LED module through the positive connective portion and/or the negative connective portion at each or both ends of the LED lamp. Thus the layout structure increases the flexibility in arranging actual circuits in the LED lamp.

FIG. **53**D is a plan view of a circuit layout of the LED module according to another embodiment of the present invention. Referring to FIG. **53**D, in this embodiment LEDs **931** are connected in the same way as described in FIG. **53**A, and three LED units each including **7** LEDs **931** are assumed in LED module **630** and described as follows for illustration. A positive conductive line **934** and a negative conductive line **935** are to receive a driving signal, for supplying power to the LEDs **931**. For example, positive conductive line **934** may be coupled to the filtering output terminal **521** of the filtering circuit **520** described above, and negative conductive line **935** coupled to the filtering output terminal **522** of the filtering circuit **520**, to receive a filtered signal. For the convenience of illustration, all seven LEDs **931** of each of the three LED units are grouped as an LED set **932** in FIG. **53**D. Thus there are three LED sets **932** corresponding to the three LED units.

Positive conductive line **934** connects to the anode on the left side of the first or leftmost LED **931** of each of the three LED sets **932**. Negative conductive line **935** connects to the cathode on the right side of the last or rightmost LED **931** of each of the three LED sets **932**. In each LED set **932** of two consecutive LEDs **931**, the LED **931** on the left has a cathode connected by a conductive part **939** to an anode of the LED **931** on the right. By such a layout, the LEDs **931** of each LED set **932** are connected in series.

It's also worth noting that a conductive part **939** may be used to connect an anode and a cathode respectively of two consecutive LEDs **931**. Negative conductive line **935** connects to the cathode of the last or rightmost LED **931** of each of the three LED sets **932**. And positive conductive line **934** connects to the anode of the first or leftmost LED **931** of each of the three LED sets **932**. Therefore, as shown in FIG. **53**D, the length (and thus area) of the conductive part **939** is larger than that of the portion of negative conductive line **935** immediately connecting to a cathode, which length (and thus area) is then larger than that of the portion of positive conductive line **934** immediately connecting to an anode. For example, the length **938** of the conductive part **939** may be larger than the length **937** of the portion of negative conductive line **935** immediately connecting to a cathode of an LED **931**, which length **937** is then larger than the length **936** of the portion of positive conductive line **934** immediately connecting to an anode of an LED **931**. Such a layout structure improves heat dissipation of the LEDs **931** in LED module **630**.

Positive conductive line **934** may include a lengthwise portion **934** a, and negative conductive line **935** may include a lengthwise portion **935***a*, which are conducive to making the LED module have a positive "+" connective portion and a negative "–" connective portion at each of the two ends of the LED module, as shown in FIG. **53**D. Such a layout structure allows for coupling any of other circuits of the power supply module of the LED lamp, including e.g. filtering circuit **520** and rectifying circuits **510** and **540**, to the LED module through the positive connective portion **934** a and/or the negative connective portion **935***a* at each or both ends of the LED lamp. Thus the layout structure increases the flexibility in arranging actual circuits in the LED lamp.

Further, the circuit layouts as shown in FIGS. **53**C and **53**D may be implemented with a bendable circuit sheet or substrate, which may even be called flexible circuit board depending on its specific definition used. For example, the bendable circuit sheet may comprise one conductive layer where positive conductive line **834**, positive lengthwise portion **834***a*, negative conductive line **835**, negative lengthwise portion **835***a*, and conductive parts **839** shown in FIG. **53**C, and positive conductive line **934**, positive lengthwise portion **934** a, negative conductive line **935**, negative lengthwise portion **935***a*, and conductive parts **939** shown in FIG. **53**D are formed by the method of etching.

FIG. **53**E is a plan view of a circuit layout of the LED module according to another embodiment of the present invention. The layout structures of the LED module in FIGS. **53**E and **53**C each correspond to the same way of connecting LEDs **831** as that shown in FIG. **53**B, but the layout structure in FIG. **53**E comprises two conductive layers, instead of only one conductive layer for forming the circuit layout as shown in FIG. **53**C. Referring to FIG. **53**E, the main difference from the layout in FIG. **53**C is that positive conductive line **834** and negative conductive line **835** have a lengthwise portion **834***a* and a lengthwise portion **835***a*, respectively, that are formed in a second conductive layer instead. The difference is elaborated as follows.

Referring to FIG. **53**E, the bendable circuit sheet of the LED module comprises a first conductive layer **2***a* and a second conductive layer **2***c* electrically insulated from each other by a dielectric layer **2***b* (not shown). Of the two conductive layers, positive conductive line **834**, negative conductive line **835**, and conductive parts **839** in FIG. **53**E are formed in first conductive layer **2***a* by the method of etching for electrically connecting the plurality of LED components **831** e.g. in a form of a mesh, whereas positive lengthwise portion **834***a* and negative lengthwise portion **835***a* are formed in second conductive layer **2***c* by etching for electrically connecting to (the filtering output terminal of) the filtering circuit. Further, positive conductive line **834** and negative conductive line **835** in first conductive layer **2***a* have via points **834***b* and via points **835***b*, respectively, for connecting to second conductive layer **2***c*. And positive lengthwise portion **834***a* and negative lengthwise portion **835***a* in second conductive layer **2***c* have via points **834***c* and via points **835***b*, respectively. Via points **834***b* are positioned corresponding to via points **834***c*, for connecting positive conductive line **834** and positive lengthwise portion **834***a*. Via points **835***b* are positioned corresponding to via points **835***b*, for connecting negative conductive line **835** and negative lengthwise portion **835***a*. A preferable way of connecting the two conductive layers is to form a hole connecting each via point **834***b* and a corresponding via point **834***c*, and to form a hole connecting each via point **835***b* and a corresponding via point **835***b*, with the holes extending through the two conductive layers and the dielectric layer in-between. And positive conductive line **834** and positive lengthwise portion **834***a* can be electrically connected by welding metallic part(s) through the connecting hole(s), and negative conductive line **835** and negative lengthwise portion **835***a* can be electrically connected by welding metallic part(s) through the connecting hole(s).

Similarly, the layout structure of the LED module in FIG. **53**D may alternatively have positive lengthwise portion **934** a and negative lengthwise portion **935***a* disposed in a second conductive layer, to constitute a two-layer layout structure.

It's worth noting that the thickness of the second conductive layer of a two-layer bendable circuit sheet is in some embodiments larger than that of the first conductive layer, in order to reduce the voltage drop or loss along each of the positive lengthwise portion and the negative lengthwise portion disposed in the second conductive layer. Compared to a one-layer bendable circuit sheet, since a positive lengthwise portion and a negative lengthwise portion are disposed in a second conductive layer in a two-layer bendable circuit sheet, the width (between two lengthwise sides) of the two-layer bendable circuit sheet is or can be reduced. On the same fixture or plate in a production process, the number of bendable circuit sheets each with a shorter width that can be laid together at most is larger than the number of bendable circuit sheets each with a longer width that can be laid together at most. Thus adopting a bendable circuit sheet with a shorter width can increase the efficiency of production of the LED module. And reliability in the production process, such as the accuracy of welding position when welding (materials on) the LED components, can also be improved, because a two-layer bendable circuit sheet can better maintain its shape.

According to the detailed description of the instant disclosure, the LED light strip may be a bendable circuit sheet, a conductive wiring layer, a dielectric layer stacked on the conductive wiring layer, a bi-layered structure, two conductive wiring layers, an elongated aluminum plate, a FR4 board, 3-layered flexible board, or multiple layers of the wiring layers and multiple layers of the dielectric layers sequentially stacked in a staggered manner.

As a variant of the above embodiments, a type of LED tube lamp is provided that has at least some of the electronic components of its power supply module disposed on a light strip of the LED tube lamp. For example, the technique of printed electronic circuit (PEC) can be used to print, insert, or embed at least some of the electronic components onto the light strip.

In one embodiment, all electronic components of the power supply module are disposed on the light strip. The production process may include or proceed with the following steps: preparation of the circuit substrate (e.g. preparation of a flexible printed circuit board); ink jet printing of metallic nano-ink; ink jet printing of active and passive components (as of the power supply module); drying/sintering; ink jet printing of interlayer bumps; spraying of insulating ink; ink jet printing of metallic nano-ink; ink jet printing of active and passive components (to sequentially form the included layers); spraying of surface bond pad(s); and spraying of solder resist against LED components.

In certain embodiments, if all electronic components of the power supply module are disposed on the light strip, electrical connection between terminal pins of the LED tube lamp and the light strip may be achieved by connecting the pins to conductive lines which are welded with ends of the light strip. In this case, another substrate for supporting the power supply module is not required, thereby allowing of an improved design or arrangement in the end cap(s) of the LED tube lamp. In some embodiments, (components of) the power supply module are disposed at two ends of the light strip, in order to significantly reduce the impact of heat generated from the power supply module's operations on the LED components. Since no substrate other than the light strip is used to support the power supply module in this case, the total amount of welding or soldering can be significantly reduced, improving the general reliability of the power supply module.

Another case is that some of all electronic components of the power supply module, such as some resistors and/or smaller size capacitors, are printed onto the light strip, and some bigger size components, such as some inductors and/or electrolytic capacitors, are disposed in the end cap(s). The production process of the light strip in this case may be the same as that described above. And in this case disposing some of all electronic components on the light strip is conducive to achieving a reasonable layout of the power supply module in the LED tube lamp, which may allow of an improved design in the end cap(s).

As a variant embodiment of the above, electronic components of the power supply module may be disposed on the light strip by a method of embedding or inserting, e.g. by embedding the components onto a bendable or flexible light strip. In some embodiments, this embedding may be realized by a method using copper-clad laminates (CCL) for forming a resistor or capacitor; a method using ink related to silkscreen printing; or a method of ink jet printing to embed passive components, wherein an ink jet printer is used to directly print inks to constitute passive components and related functionalities to intended positions on the light strip. Then through treatment by ultraviolet (UV) light or drying/sintering, the light strip is formed where passive components are embedded. The electronic components embedded onto the light strip include for example resistors, capacitors, and

inductors. In other embodiments, active components also may be embedded. Through embedding some components onto the light strip, a reasonable layout of the power supply module can be achieved to allow of an improved design in the end cap(s), because the surface area on a printed circuit board used for carrying components of the power supply module is reduced or smaller, and as a result the size, weight, and thickness of the resulting printed circuit board for carrying components of the power supply module is also smaller or reduced. Also in this situation since welding points on the printed circuit board for welding resistors and/or capacitors if they were not to be disposed on the light strip are no longer used, the reliability of the power supply module is improved, in view of the fact that these welding points are most liable to (cause or incur) faults, malfunctions, or failures. Further, the length of conductive lines needed for connecting components on the printed circuit board is therefore also reduced, which allows of a more compact layout of components on the printed circuit board and thus improving the functionalities of these components.

Next, methods to produce embedded capacitors and resistors are explained as follows.

Usually, methods for manufacturing embedded capacitors employ or involve a concept called distributed or planar capacitance. The manufacturing process may include the following step(s). On a substrate of a copper layer a very thin insulation layer is applied or pressed, which is then generally disposed between a pair of layers including a power conductive layer and a ground layer. The very thin insulation layer makes the distance between the power conductive layer and the ground layer very short. A capacitance resulting from this structure can also be realized by a technique of a plated-through hole. Basically, this step is used to create this structure comprising a big parallel-plate capacitor on a circuit substrate.

Of products of high electrical capacity, certain types of products employ distributed capacitances, and other types of products employ separate embedded capacitances. Through putting or adding a high dielectric-constant material such as barium titanate into the insulation layer, the high electrical capacity is achieved.

A usual method for manufacturing embedded resistors employ conductive or resistive adhesive. This may include, for example, a resin to which conductive carbon or graphite is added, which may be used as an additive or filler. The additive resin is silkscreen printed to an object location, and is then after treatment laminated inside the circuit board. The resulting resistor is connected to other electronic components through plated-through holes or microvias. Another method is called Ohmega-Ply, by which a two metallic layer structure of a copper layer and a thin nickel alloy layer constitutes a layer resistor relative to a substrate. Then through etching the copper layer and nickel alloy layer, different types of nickel alloy resistors with copper terminals can be formed. These types of resistor are each laminated inside the circuit board.

In an embodiment, conductive wires/lines are directly printed in a linear layout on an inner surface of the LED glass lamp tube, with LED components directly attached on the inner surface and electrically connected by the conductive wires. In some embodiments, the LED components in the form of chips are directly attached over the conductive wires on the inner surface, and connective points are at terminals of the wires for connecting the LED components and the power supply module. After being attached, the LED chips may have fluorescent powder applied or dropped thereon, for producing white light or light of other color by the operating LED tube lamp.

In some embodiments, luminous efficacy of the LED or LED component is 80 lm/W or above, and in some embodiments, it may be 120 lm/W or above. Certain more optimal embodiments may include a luminous efficacy of the LED or LED component of 160 lm/W or above. White light emitted by an LED component in the invention may be produced by mixing fluorescent powder with the monochromatic light emitted by a monochromatic LED chip. The white light in its spectrum has major wavelength ranges of 430-460 nm and 550-560 nm, or major wavelength ranges of 430-460 nm, 540-560 nm, and 620-640 nm.

FIG. **54**A is a block diagram of a power supply module in an LED lamp according to an embodiment of the present invention. As shown in FIG. **54**A, the power supply module of the LED lamp includes two rectifying circuits **510** and **540**, a filtering circuit **520**, and a driving circuit **1530**. In this embodiment, a driving circuit **1530** and an LED module **630** compose the LED lighting module **530**. The driving circuit **1530** comprises a DC-to-DC converter circuit, and is coupled to the filtering output terminals **521** and **522** to receive a filtered signal and then perform power conversion for converting the filtered signal into a driving signal at the driving output terminals **1521** and **1522**. The LED module **630** is coupled to the driving output terminals **1521** and **1522** to receive the driving signal for emitting light. In some embodiments, the current of LED module **630** is stabilized at an objective current value. Descriptions of this LED module **630** are the same as those provided above with reference to FIGS. **53**A-D.

FIG. **54**B is a block diagram of the driving circuit according to an embodiment of the present invention. Referring to FIG. **54**B, a driving circuit includes a controller **1531**, and a conversion circuit **1532** for power conversion based on a current source, for driving the LED module to emit light. The conversion circuit **1532** includes a switching circuit **1535** and an energy storage circuit **1538**. And the conversion circuit **1532** is coupled to the filtering output terminals **521** and **522** to receive and then convert a filtered signal, under the control by the controller **1531**, into a driving signal at the driving output terminals **1521** and **1522** for driving the LED module. Under the control by the controller **1531**, the driving signal output by the conversion circuit **1532** comprises a steady current, making the LED module emitting steady light.

FIG. **54**C is a schematic diagram of the driving circuit according to an embodiment of the present invention. Referring to FIG. **54**C, a driving circuit **1630** in this embodiment comprises a buck DC-to-DC converter circuit having a controller **1631** and a converter circuit. The converter circuit includes an inductor **1632**, a diode **1633** for “freewheeling” of current, a capacitor **1634**, and a switch **1635**. The driving circuit **1630** is coupled to the filtering output terminals **521** and **522** to receive and then convert a filtered signal into a driving signal for driving an LED module connected between the driving output terminals **1521** and **1522**.

In this embodiment, the switch **1635** comprises a metal-oxide-semiconductor field-effect transistor (MOSFET) and has a first terminal coupled to the anode of freewheeling diode **1633**, a second terminal coupled to the filtering output terminal **522**, and a control terminal coupled to the controller **1631** used for controlling current conduction or cutoff between the first and second terminals of switch **1635**. The driving output terminal **1521** is connected to the filtering output terminal **521**, and the driving output terminal **1522** is connected to an end of the inductor **1632**, which has another

end connected to the first terminal of switch **1635**. The capacitor **1634** is coupled between the driving output terminals **1521** and **1522** to stabilize the voltage between the driving output terminals **1521** and **1522**. The freewheeling diode **1633** has a cathode connected to the driving output terminal **1521**.

Next, a description follows as to an exemplary operation of the driving circuit **1630**.

The controller **1631** is configured for determining when to turn the switch **1635** on (in a conducting state) or off (in a cutoff state) according to a current detection signal S**535** and/or a current detection signal **5531**. For example, in some embodiments, the controller **1631** is configured to control the duty cycle of switch **1635** being on and switch **1635** being off in order to adjust the size or magnitude of the driving signal. The current detection signal S**535** represents the magnitude of current through the switch **1635**. The current detection signal **5531** represents the magnitude of current through the LED module coupled between the driving output terminals **1521** and **1522**. According to any of current detection signal S**535** and current detection signal **5531**, the controller **1631** can obtain information on the magnitude of power converted by the converter circuit. When the switch **1635** is switched on, a current of a filtered signal is input through the filtering output terminal **521**, and then flows through the capacitor **1634**, the driving output terminal **1521**, the LED module, the inductor **1632**, and the switch **1635**, and then flows out from the filtering output terminal **522**. During this flowing of current, the capacitor **1634** and the inductor **1632** are performing storing of energy. On the other hand, when the switch **1635** is switched off, the capacitor **1634** and the inductor **1632** perform releasing of stored energy by a current flowing from the freewheeling diode **1633** to the driving output terminal **1521** to make the LED module continuing to emit light.

It’s worth noting that the capacitor **1634** is an optional element, so it can be omitted and is thus depicted in a dotted line in FIG. **54**C. In some application environments, the natural characteristic of an inductor to oppose instantaneous change in electric current passing through the inductor may be used to achieve the effect of stabilizing the current through the LED module, thus omitting the capacitor **1634**.

FIG. **54**D is a schematic diagram of the driving circuit according to an embodiment of the present invention. Referring to FIG. **54**D, a driving circuit **1730** in this embodiment comprises a boost DC-to-DC converter circuit having a controller **1731** and a converter circuit. The converter circuit includes an inductor **1732**, a diode **1733** for “freewheeling” of current, a capacitor **1734**, and a switch **1735**. The driving circuit **1730** is configured to receive and then convert a filtered signal from the filtering output terminals **521** and **522** into a driving signal for driving an LED module coupled between the driving output terminals **1521** and **1522**.

The inductor **1732** has an end connected to the filtering output terminal **521**, and another end connected to the anode of freewheeling diode **1733** and a first terminal of the switch **1735**, which has a second terminal connected to the filtering output terminal **522** and the driving output terminal **1522**. The freewheeling diode **1733** has a cathode connected to the driving output terminal **1521**. And the capacitor **1734** is coupled between the driving output terminals **1521** and **1522**.

The controller **1731** is coupled to a control terminal of switch **1735**, and is configured for determining when to turn the switch **1735** on (in a conducting state) or off (in a cutoff state), according to a current detection signal S**535** and/or a current detection signal S**531**. When the switch **1735** is switched on, a current of a filtered signal is input through the filtering output terminal **521**, and then flows through the inductor **1732** and the switch **1735**, and then flows out from the filtering output terminal **522**. During this flowing of current, the current through the inductor **1732** increases with time, with the inductor **1732** being in a state of storing energy, while the capacitor **1734** enters a state of releasing energy, making the LED module continuing to emit light. On the other hand, when the switch **1735** is switched off, the inductor **1732** enters a state of releasing energy as the current through the inductor **1732** decreases with time. In this state, the current through the inductor **1732** then flows through the freewheeling diode **1733**, the capacitor **1734**, and the LED module, while the capacitor **1734** enters a state of storing energy.

It's worth noting that the capacitor **1734** is an optional element, so it can be omitted and is thus depicted in a dotted line in FIG. **54**D. When the capacitor **1734** is omitted and the switch **1735** is switched on, the current of inductor **1732** does not flow through the LED module, making the LED module not emit light; but when the switch **1735** is switched off, the current of inductor **1732** flows through the freewheeling diode **1733** to reach the LED module, making the LED module emit light. Therefore, by controlling the time that the LED module emits light, and the magnitude of current through the LED module, the average luminance of the LED module can be stabilized to be above a defined value, thus also achieving the effect of emitting a steady light.

FIG. **54**E is a schematic diagram of the driving circuit according to an embodiment of the present invention. Referring to FIG. **54**E, a driving circuit **1830** in this embodiment comprises a buck DC-to-DC converter circuit having a controller **1831** and a converter circuit. The converter circuit includes an inductor **1832**, a diode **1833** for "freewheeling" of current, a capacitor **1834**, and a switch **1835**. The driving circuit **1830** is coupled to the filtering output terminals **521** and **522** to receive and then convert a filtered signal into a driving signal for driving an LED module connected between the driving output terminals **1521** and **1522**.

The switch **1835** has a first terminal coupled to the filtering output terminal **521**, a second terminal coupled to the cathode of freewheeling diode **1833**, and a control terminal coupled to the controller **1831** to receive a control signal from the controller **1831** for controlling current conduction or cutoff between the first and second terminals of the switch **1835**. The anode of freewheeling diode **1833** is connected to the filtering output terminal **522** and the driving output terminal **1522**. The inductor **1832** has an end connected to the second terminal of switch **1835**, and another end connected to the driving output terminal **1521**. The capacitor **1834** is coupled between the driving output terminals **1521** and **1522** to stabilize the voltage between the driving output terminals **1521** and **1522**.

The controller **1831** is configured for controlling when to turn the switch **1835** on (in a conducting state) or off (in a cutoff state) according to a current detection signal S**535** and/or a current detection signal **5531**. When the switch **1835** is switched on, a current of a filtered signal is input through the filtering output terminal **521**, and then flows through the switch **1835**, the inductor **1832**, and the driving output terminals **1521** and **1522**, and then flows out from the filtering output terminal **522**. During this flowing of current, the current through the inductor **1832** and the voltage of the capacitor **1834** both increase with time, so the inductor **1832** and the capacitor **1834** are in a state of storing energy. On the other hand, when the switch **1835** is switched off, the

inductor **1832** is in a state of releasing energy and thus the current through it decreases with time. In this case, the current through the inductor **1832** circulates through the driving output terminals **1521** and **1522**, the freewheeling diode **1833**, and back to the inductor **1832**.

It's worth noting that the capacitor **1834** is an optional element, so it can be omitted and is thus depicted in a dotted line in FIG. **54**E. When the capacitor **1834** is omitted, no matter whether the switch **1835** is turned on or off, the current through the inductor **1832** will flow through the driving output terminals **1521** and **1522** to drive the LED module to continue emitting light.

FIG. **54**F is a schematic diagram of the driving circuit according to an embodiment of the present invention. Referring to FIG. **54**F, a driving circuit **1930** in this embodiment comprises a buck DC-to-DC converter circuit having a controller **1931** and a converter circuit. The converter circuit includes an inductor **1932**, a diode **1933** for "freewheeling" of current, a capacitor **1934**, and a switch **1935**. The driving circuit **1930** is coupled to the filtering output terminals **521** and **522** to receive and then convert a filtered signal into a driving signal for driving an LED module connected between the driving output terminals **1521** and **1522**.

The inductor **1932** has an end connected to the filtering output terminal **521** and the driving output terminal **1522**, and another end connected to a first end of the switch **1935**. The switch **1935** has a second end connected to the filtering output terminal **522**, and a control terminal connected to controller **1931** to receive a control signal from controller **1931** for controlling current conduction or cutoff of the switch **1935**. The freewheeling diode **1933** has an anode coupled to a node connecting the inductor **1932** and the switch **1935**, and a cathode coupled to the driving output terminal **1521**. The capacitor **1934** is coupled to the driving output terminals **1521** and **1522** to stabilize the driving of the LED module coupled between the driving output terminals **1521** and **1522**.

The controller **1931** is configured for controlling when to turn the switch **1935** on (in a conducting state) or off (in a cutoff state) according to a current detection signal S**531** and/or a current detection signal S**535**. When the switch **1935** is turned on, a current is input through the filtering output terminal **521**, and then flows through the inductor **1932** and the switch **1935**, and then flows out from the filtering output terminal **522**.

During this flowing of current, the current through the inductor **1932** increases with time, so the inductor **1932** is in a state of storing energy; but the voltage of the capacitor **1934** decreases with time, so the capacitor **1934** is in a state of releasing energy to keep the LED module continuing to emit light. On the other hand, when the switch **1935** is turned off, the inductor **1932** is in a state of releasing energy and its current decreases with time. In this case, the current through the inductor **1932** circulates through the freewheeling diode **1933**, the driving output terminals **1521** and **1522**, and back to the inductor **1932**. During this circulation, the capacitor **1934** is in a state of storing energy and its voltage increases with time.

It's worth noting that the capacitor **1934** is an optional element, so it can be omitted and is thus depicted in a dotted line in FIG. **54**F. When the capacitor **1934** is omitted and the switch **1935** is turned on, the current through the inductor **1932** doesn't flow through the driving output terminals **1521** and **1522**, thereby making the LED module not emit light. On the other hand, when the switch **1935** is turned off, the current through the inductor **1932** flows through the freewheeling diode **1933** and then the LED module to make the

LED module emit light. Therefore, by controlling the time that the LED module emits light, and the magnitude of current through the LED module, the average luminance of the LED module can be stabilized to be above a defined value, thus also achieving the effect of emitting a steady light.

FIG. **54**G is a block diagram of the driving circuit according to an embodiment of the present invention. Referring to FIG. **54**G, the driving circuit includes a controller **2631**, and a conversion circuit **2632** for power conversion based on an adjustable current source, for driving the LED module to emit light. The conversion circuit **2632** includes a switching circuit **2635** and an energy storage circuit **2638**. And the conversion circuit **2632** is coupled to the filtering output terminals **521** and **522** to receive and then convert a filtered signal, under the control by the controller **2631**, into a driving signal at the driving output terminals **1521** and **1522** for driving the LED module. The controller **2631** is configured to receive a current detection signal S**535** and/or a current detection signal S**539** for controlling or stabilizing the driving signal output by the conversion circuit **2632** to be above an objective current value. The current detection signal S**535** represents the magnitude of current through the switching circuit **2635**. The current detection signal S**539** represents the magnitude of current through energy storage circuit **2638**, which current may be e.g. an inductor current in energy storage circuit **2638** or a current output at the driving output terminal **1521**. Any of current detection signal S**535** and current detection signal S**539** can represent the magnitude of current Iout provided by the driving circuit from the driving output terminals **1521** and **1522** to the LED module. The controller **2631** is coupled to the filtering output terminal **521** for setting the objective current value according to the voltage Vin at the filtering output terminal **521**. Therefore, the current Iout provided by the driving circuit or the objective current value can be adjusted corresponding to the magnitude of the voltage Vin of a filtered signal output by a filtering circuit.

It's worth noting that current detection signals S**535** and S**539** can be generated by measuring current through a resistor or induced by an inductor. For example, a current can be measured according to a voltage drop across a resistor in the conversion circuit **2632** the current flows through, or which arises from a mutual induction between an inductor in the conversion circuit **2632** and another inductor in its energy storage circuit **2638**.

The above driving circuit structures are especially suitable for an application environment in which the external driving circuit for the LED tube lamp includes electronic ballast. An electronic ballast is equivalent to a current source whose output power is not constant. In an internal driving circuit as shown in each of FIGS. **54**C-F, power consumed by the internal driving circuit relates to or depends on the number of LEDs in the LED module, and could be regarded as constant. When the output power of the electronic ballast is higher than power consumed by the LED module driven by the driving circuit, the output voltage of the ballast will increase continually, causing the logic level of an AC driving signal received by the power supply module of the LED lamp to continually increase, so as to risk damaging the ballast and/or components of the power supply module due to their voltage ratings being exceeded. On the other hand, when the output power of the electronic ballast is lower than power consumed by the LED module driven by the driving circuit, the output voltage of the ballast and the logic level of the AC driving signal will decrease continually so that the LED tube lamp fail to normally operate.

It's worth noting that the power needed for an LED lamp to work is already lower than that needed for a fluorescent lamp to work. If a conventional control mechanism of e.g. using a backlight module to control the LED luminance is used with a conventional driving system of e.g. a ballast, a problem will probably arise of mismatch or incompatibility between the output power of the external driving system and the power needed by the LED lamp. This problem may even cause damaging of the driving system and/or the LED lamp. To prevent or reduce this problem, using e.g. the power/current adjustment method described above in FIG. **54**G enables the LED (tube) lamp to be better compatible with traditional fluorescent lighting system.

FIG. **54**H is a graph illustrating the relationship between the voltage Vin and the objective current value Iout according to an embodiment of the present invention. In FIG. **54**H, the variable Vin is on the horizontal axis, and the variable Iout is on the vertical axis. In some cases, when the logic level of the voltage Vin of a filtered signal is between the upper voltage limit VH and the lower voltage limit VL, the objective current value Iout will be about an initial objective current value. The upper voltage limit VH is higher than the lower voltage limit VL. When the voltage Vin increases to be higher than the upper voltage limit VH, the objective current value Iout will increase with the increasing of the voltage Vin. During this stage, a situation that may be preferable is that the slope of the relationship curve increase with the increasing of the voltage Vin. When the voltage Vin of a filtered signal decreases to be below the lower voltage limit VL, the objective current value Iout will decrease with the decreasing of the voltage Vin. During this stage, a situation that may be preferable is that the slope of the relationship curve decrease with the decreasing of the voltage Vin. For example, during the stage when the voltage Vin is higher than the upper voltage limit VH or lower than the lower voltage limit VL, the objective current value Iout is in some embodiments a function of the voltage Vin to the power of 2 or above, in order to make the rate of increase/decrease of the consumed power higher than the rate of increase/decrease of the output power of the external driving system. Thus, adjustment of the objective current value Iout is in some embodiments a function of the filtered voltage Vin to the power of 2 or above.

In another case, when the voltage Vin of a filtered signal is between the upper voltage limit VH and the lower voltage limit VL, the objective current value Iout of the LED lamp will vary, increase or decrease, linearly with the voltage Vin. During this stage, when the voltage Vin is at the upper voltage limit VH, the objective current value Iout will be at the upper current limit IH. When the voltage Vin is at the lower voltage limit VL, the objective current value Iout will be at the lower current limit IL. The upper current limit IH is larger than the lower current limit IL. And when the voltage Vin is between the upper voltage limit VH and the lower voltage limit VL, the objective current value Iout will be a function of the voltage Vin to the power of 1.

With the designed relationship in FIG. **54**H, when the output power of the ballast is higher than the power consumed by the LED module driven by the driving circuit, the voltage Vin will increase with time to exceed the upper voltage limit VH. When the voltage Vin is higher than the upper voltage limit VH, the rate of increase of the consumed power of the LED module is higher than that of the output power of the electronic ballast, and the output power and the consumed power will be balanced or equal when the voltage Vin is at a high balance voltage value VH+ and the current Iout is at a high balance current value IH+. In this case, the high balance voltage value VH+ is larger than the upper voltage limit VH, and the high balance current value IH+ is larger than the upper current limit IH. On the other hand, when the output power of the ballast is lower than the power consumed by the LED module driven by the driving circuit, the voltage Vin will be below the lower voltage limit VL. When the voltage Vin is lower than the lower voltage limit VL, the rate of decrease of the consumed power of the LED module is higher than that of the output power of the electronic ballast, and the output power and the consumed power will be balanced or equal when the voltage Vin is at a low balance voltage value VL− and the objective current value Iout is at a low balance current value IL−. In this case, the low balance voltage value VL− is smaller than the lower voltage limit VL, and the low balance current value IL− is smaller than the lower current limit IL.

In some embodiments, the lower voltage limit VL is defined to be around 90% of the lowest output power of the electronic ballast, and the upper voltage limit VH is defined to be around 110% of its highest output power. Taking a common AC powerline with a voltage range of 100-277 volts and a frequency of 60 Hz as an example, the lower voltage limit VL may be set at 90 volts (=100*90%), and the upper voltage limit VH may be set at 305 volts (=277*110%).

With reference to FIGS. **19** and **20**, a short circuit board **253** includes a first short circuit substrate and a second short circuit substrate respectively connected to two terminal portions of a long circuit sheet **251**, and electronic components of the power supply module are respectively disposed on the first short circuit substrate and the second short circuit substrate. The first short circuit substrate and the second short circuit substrate may have roughly the same length, or different lengths. In general, the first short circuit substrate (i.e. the right circuit substrate of short circuit board **253** in FIG. **19** and the left circuit substrate of short circuit board **253** in FIG. **20**) has a length that is about 30%-80% of the length of the second short circuit substrate (i.e. the left circuit substrate of short circuit board **253** in FIG. **19** and the right circuit substrate of short circuit board **253** in FIG. **20**). In some embodiments the length of the first short circuit substrate is about ⅓~⅔ of the length of the second short circuit substrate. For example, in one embodiment, the length of the first short circuit substrate may be about half the length of the second short circuit substrate. The length of the second short circuit substrate may be, for example in the range of about 15 mm to about 65 mm, depending on actual application occasions. In certain embodiments, the first short circuit substrate is disposed in an end cap at an end of the LED tube lamp, and the second short circuit substrate is disposed in another end cap at the opposite end of the LED tube lamp.

For example, capacitors of the driving circuit, such as the capacitors **1634**, **1734**, **1834**, and **1934** in FIGS. **54**C-**54**F, in practical use may include two or more capacitors connected in parallel. Some or all capacitors of the driving circuit in the power supply module may be arranged on the first short circuit substrate of short circuit board **253**, while other components such as the rectifying circuit, filtering circuit, inductor(s) of the driving circuit, controller(s), switch(es), diodes, etc. are arranged on the second short circuit substrate of short circuit board **253**. Since the inductors, controllers, switches, etc. are electronic components with higher temperature, arranging some or all capacitors on a circuit substrate separate or away from the circuit substrate(s) of high-temperature components helps prevent the working life of capacitors (especially electrolytic capacitors) from being negatively affected by the high-temperature components, thus improving the reliability of the capacitors. Further, the physical separation between the capacitors and both the rectifying circuit and filtering circuit also contributes to reducing the problem of EMI.

In some embodiments, the driving circuit has power conversion efficiency of 80% or above, which may be 90% or above, and may even be 92% or above. Therefore, without the driving circuit, luminous efficacy of the LED lamp according to some embodiments may be 120 lm/W or above, and may even be 160 lm/W or above. On the other hand, with the driving circuit in combination with the LED component(s), luminous efficacy of the LED lamp in the invention may be, in some embodiments, 120 lm/W*90%=108 lm/W or above, and may even be, in some embodiments 160 lm/W*92%=147.2 lm/W or above.

In view of the fact that the diffusion film or layer in an LED tube lamp has light transmittance of 85% or above, luminous efficacy of the LED tube lamp of the invention is in some embodiments 108 lm/W*85%=91.8 lm/W or above, and may be, in some more effective embodiments, 147.2 lm/W*85%=125.12 lm/W.

FIG. **55**A is a block diagram of using a power supply module in an LED lamp according to an embodiment of the present invention. Compared to FIG. **49**B, the embodiment of FIG. **55**A includes two rectifying circuits **510** and **540**, a filtering circuit **520**, and a driving circuit **1530**, and further includes an anti-flickering circuit **550** coupled between the filtering circuit **520** and the LED lighting module **530**. In this embodiment, a driving circuit **1530** and an LED module **630** compose the LED lighting module **530**.

The anti-flickering circuit **550** is coupled to the filtering output terminals **521** and **522** to receive a filtered signal, and under specific circumstances to consume partial energy of the filtered signal so as to reduce (the incidence of) ripples of the filtered signal disrupting or interrupting the light emission of the LED lighting module **530**. In general, the filtering circuit **520** has such filtering components as capacitor(s) and/or inductor(s), and/or parasitic capacitors and inductors, which may form resonant circuits. Upon breakoff or stop of an AC power signal, as when the power supply of the LED lamp is turned off by a user, the amplitude(s) of resonant signals in the resonant circuits will decrease with time. But LEDs in the LED module of the LED lamp are unidirectional conduction devices and generally require a minimum conduction voltage for the LED module. When a resonant signal's trough value is lower than the minimum conduction voltage of the LED module, but its peak value is still higher than the minimum conduction voltage, the flickering phenomenon will occur in light emission of the LED module. In this case the anti-flickering circuit **550** works by allowing a current matching a defined flickering current value of the LED component to flow through, consuming partial energy of the filtered signal which should be higher than the energy difference of the resonant signal between its peak and trough values, so as to reduce the flickering phenomenon. In certain embodiments, a preferred occasion for the anti-flickering circuit **550** to work is when the filtered signal's voltage approaches (and is still higher than) the minimum conduction voltage, and thus the partial energy of the filtered signal consumed by the anti-flickering circuit **550** is higher than the energy difference of the resonant signal between its peak and trough values.

It's worth noting that the anti-flickering circuit **550** may be more suitable for the situation in which the LED lighting module **530** doesn't include the driving circuit **1530**, for example, when the LED module **630** of LED lighting module **530** is (directly) driven to emit light by a filtered signal from a filtering circuit. In this case, the light emission of LED module **630** will directly reflect variation in the filtered signal due to its ripples. In this situation, the introduction of anti-flickering circuit **550** will prevent the flickering phenomenon from occurring in the LED lamp upon the breakoff of power supply to the LED lamp.

FIG. **55**B is a schematic diagram of the anti-flickering circuit according to an embodiment of the present invention. Referring to FIG. **55**B, an anti-flickering circuit **650** includes at least a resistor, such as two resistors connected in series between the filtering output terminals **521** and **522**. In this embodiment, the anti-flickering circuit **650** in use consumes partial energy of a filtered signal continually. When in normal operation of the LED lamp, this partial energy is far lower than the energy consumed by LED lighting module **530**. But upon a breakoff or stop of the power supply, when the voltage logic level of the filtered signal decreases to approach the minimum conduction voltage of LED module **630**, this partial energy is still consumed by the anti-flickering circuit **650** in order to offset the impact of the resonant signals which may cause the flickering of light emission of LED module **630**. In some embodiments, a current equal to or larger than an anti-flickering current logic level may be set to flow through the anti-flickering circuit **650** when the LED module **630** is supplied by the minimum conduction voltage, and then an equivalent anti-flickering resistance of anti-flickering circuit **650** can be determined based on the set current.

FIG. **56**A is a block diagram of using a power supply module in an LED lamp according to an embodiment of the present invention. Compared to FIG. **55**A, the embodiment of FIG. **56**A includes two rectifying circuits **510** and **540**, a filtering circuit **520**, a driving circuit **1530**, and an anti-flickering circuit **550**, and further includes a protection circuit **560**. In this embodiment, a driving circuit **1530** and an LED module **630** compose the LED lighting module **530**. The protection circuit **560** is coupled to the filtering output terminals **521** and **522** to detect the filtered signal from the filtering circuit **520** for determining whether to enter a protection state. Upon entering a protection state, the protection circuit **560** works to limit, restrain, or clamp down on the logic level of the filtered signal, preventing damaging of components in the LED lighting module **530**. And the anti-flickering circuit **550** may be omitted and are thus depicted in a dotted line in FIG. **56**A.

FIG. **56**B is a schematic diagram of the protection circuit according to an embodiment of the present invention. Referring to FIG. **56**B, a protection circuit **660** includes a voltage clamping circuit, a voltage division circuit, two capacitors **663** and **670**, a resistor **669**, and a diode **672**, for entering a protection state when a current and/or voltage of the LED module is/are or might be excessively high, thus preventing damaging of the LED module. The voltage clamping circuit includes a bidirectional triode thyristor (TRIAC) **661** and a DIAC or symmetrical trigger diode **662**. The voltage division circuit includes two bipolar junction transistors (BJT) **667** and **668** and multiple resistors **664**, **665**, **666**, and **671**.

The bidirectional triode thyristor **661** has a first terminal connected to the filtering output terminal **521**, a second terminal connected to the filtering output terminal **522**, and a control terminal connected to a first terminal of symmetrical trigger diode **662**, which has a second terminal connected to an end of the capacitor **663**, which has another end connected to the filtering output terminal **522**. The resistor **664** is in parallel to the capacitor **663**, and has an end connected to the second terminal of symmetrical trigger diode **662** and another end connected to the filtering output terminal **522**. The resistor **665** has an end connected to the second terminal of symmetrical trigger diode **662** and another end connected to the collector terminal of BJT **667**, whose emitter terminal is connected to the filtering output terminal **522**. The resistor **666** has an end connected to the second terminal of symmetrical trigger diode **662** and another end connected to the collector terminal of BJT **668** and the base terminal of BJT **667**. The emitter terminal of BJT **668** is connected to the filtering output terminal **522**. The resistor **669** has an end connected to the base terminal of BJT **668** and another end connected to an end of the capacitor **670**, which has another end connected to the filtering output terminal **522**. The resistor **671** has an end connected to the second terminal of symmetrical trigger diode **662** and another end connected to the cathode of diode **672**, whose anode is connected to the filtering output terminal **521**.

It's worth noting that according to some embodiments, the resistance of resistor **665** should be smaller than that of resistor **666**.

Next, an exemplary operation of the protection circuit **660** in overcurrent protection is described as follows.

The node connecting the resistor **669** and the capacitor **670** is to receive a current detection signal S**531**, which represents the magnitude of current through the LED module. The other end of the resistor **671** is a voltage terminal **521'**. In this embodiment concerning overcurrent protection, the voltage terminal **521'** may be coupled to a biasing voltage source, or be connected through the diode **672** to the filtering output terminal **521**, as shown in FIG. **56**B, to take a filtered signal as a biasing voltage source. If the voltage terminal **521'** is coupled to an external biasing voltage source, the diode **672** may be omitted, so it is depicted in a dotted line in FIG. **56**B. The combination of the resistor **669** and the capacitor **670** can work to filter out high frequency components of the current detection signal S**531**, and then input the filtered current detection signal S**531** to the base terminal of BJT **668** for controlling current conduction and cutoff of the BJT **668**. The filtering function of the resistor **669** and the capacitor **670** can prevent misoperation of the BJT **668** due to noises. In practical use, the resistor **669** and the capacitor **670** may be omitted, so they are each depicted in a dotted line in FIG. **56**B. When they are omitted, the current detection signal S**531** is input directly to the base terminal of the BJT **668**.

When the LED lamp is operating normally and the current of the LED module is within a normal range, the BJT **668** is in a cutoff state, and the resistor **666** works to pull up the base voltage of the BJT **667**, which therefore enters a conducting state. In this state, the electric potential at the second terminal of the symmetrical trigger diode **662** is determined based on the voltage at the voltage terminal **521'** of the biasing voltage source and voltage division ratios between the resistor **671** and the parallel-connected resistors **664** and **665**. Since the resistance of resistor **665** is relatively small, voltage share for the resistor **665** is smaller and the electric potential at the second terminal of the symmetrical trigger diode **662** is therefore pulled down. Then, the electric potential at the control terminal of the bidirectional triode thyristor **661** is in turn pulled down by the symmetrical trigger diode **662**, causing the bidirectional triode thyristor **661** to enter a cutoff state, which cutoff state makes the protection circuit **660** not being in a protection state.

When the current of the LED module exceeds an overcurrent value, the logic level of current detection signal S**531** will increase significantly to cause the BJT **668** to enter a conducting state and then pull down the base voltage of the BJT **667**, which thereby enters a cutoff state. In this case, the electric potential at the second terminal of the symmetrical trigger diode **662** is determined based on the voltage at the voltage terminal **521'** of the biasing voltage source and voltage division ratios between the resistor **671** and the parallel-connected resistors **664** and **666**. Since the resistance of resistor **666** is relatively high, voltage share for the resistor **666** is larger and the electric potential at the second terminal of symmetrical trigger diode **662** is therefore higher. Then the electric potential at the control terminal of bidirectional triode thyristor **661** is in turn pulled up by the symmetrical trigger diode **662**, causing the bidirectional triode thyristor **661** to enter a conducting state, which conducting state works to restrain or clamp down on the voltage between the filtering output terminals **521** and **522** and thus makes the protection circuit **660** being in a protection state.

In this embodiment, the voltage at the voltage terminal **521'** of the biasing voltage source is determined based on the trigger voltage of the bidirectional triode thyristor **661**, and voltage division ratio between the resistor **671** and the parallel-connected resistors **664** and **665**, or voltage division ratio between the resistor **671** and the parallel-connected resistors **664** and **666**. Through voltage division between the resistor **671** and the parallel-connected resistors **664** and **665**, the voltage from the voltage terminal **521'** at the symmetrical trigger diode **662** will be lower than the trigger voltage of the bidirectional triode thyristor **661**. Otherwise, through voltage division between the resistor **671** and the parallel-connected resistors **664** and **666**, the voltage from the voltage terminal **521'** at the symmetrical trigger diode **662** will be higher than the trigger voltage of the bidirectional triode thyristor **661**. For example, in some embodiments, when the current of the LED module exceeds an overcurrent value, the voltage division circuit is adjusted to the voltage division ratio between the resistor **671** and the parallel-connected resistors **664** and **666**, causing a higher portion of the voltage at the voltage terminal **521'** to result at the symmetrical trigger diode **662**, achieving a hysteresis function. Specifically, the BJTs **667** and **668** as switches are respectively connected in series to the resistors **665** and **666** which determine the voltage division ratios. The voltage division circuit is configured to control turning on which one of the BJTs **667** and **668** and leaving the other off for determining the relevant voltage division ratio, according to whether the current of the LED module exceeds an overcurrent value. And the clamping circuit determines whether to restrain or clamp down on the voltage of the LED module according to the applying voltage division ratio.

Next, an exemplary operation of the protection circuit **660** in overvoltage protection is described as follows.

The node connecting the resistor **669** and the capacitor **670** is to receive a current detection signal **5531**, which represents the magnitude of current through the LED module. As described above, the protection circuit **660** still works to provide overcurrent protection. The other end of resistor **671** is a voltage terminal **521'**. In this embodiment concerning overvoltage protection, the voltage terminal **521'** is coupled to the positive terminal of the LED module to detect the voltage of the LED module. Taking previously described embodiments for example, in embodiments of FIGS. **53**A and **53**B, the LED lighting module **530** doesn't include the driving circuit **1530**, and the voltage terminal **521'** would be coupled to the filtering output terminal **521**. Whereas in embodiments of FIGS. **54**A-**54**G, the LED lighting module **530** includes the driving circuit **1530**, and the voltage terminal **521'** would be coupled to the driving output terminal **1521**. In this embodiment, voltage division ratios between the resistor **671** and the parallel-connected resistors **664** and **665**, and voltage division ratios between the resistor **671** and the parallel-connected resistors **664** and **666** will be adjusted according to the voltage at the voltage terminal **521'**, for example, the voltage at the driving output terminal **1521** or the filtering output terminal **521**. Therefore, normal overcurrent protection can still be provided by the protection circuit **660**.

In some embodiments, when the LED lamp is operating normally, assuming overcurrent condition doesn't occur, the electric potential at the second terminal of the symmetrical trigger diode **662** is determined based on the voltage at the voltage terminal **521'** and voltage division ratios between the resistor **671** and the parallel-connected resistors **664** and **665**, and is insufficient to trigger the bidirectional triode thyristor **661**. Then the bidirectional triode thyristor **661** is in a cutoff state, making the protection circuit **660** not being in a protection state. On the other hand, when the LED module is operating abnormally with the voltage at the positive terminal of the LED module exceeding an overvoltage value, the electric potential at the second terminal of symmetrical trigger diode **662** is sufficiently high to trigger the bidirectional triode thyristor **661** when the voltage at the first terminal of the symmetrical trigger diode **662** is larger than the trigger voltage of the bidirectional triode thyristor **661**. Then the bidirectional triode thyristor **661** enters a conducting state, making the protection circuit **660** being in a protection state to restrain or clamp down on the logic level of the filtered signal.

As described above, the protection circuit **660** provides one or two of the functions of overcurrent protection and overvoltage protection.

In some embodiments, the protection circuit **660** may further include a zener diode connected to the resistor **664** in parallel, which zener diode is used to limit or restrain the voltage across the resistor **664**. The breakdown voltage of the zener diode is in some embodiments in the range of about 25-50 volts, and in some embodiments may be about 36 volts.

Further, a silicon controlled rectifier may be substituted for the bidirectional triode thyristor **661**, without negatively affecting the protection functions. Using a silicon controlled rectifier instead of a bidirectional triode thyristor **661** has a lower voltage drop across itself in conduction than that across the bidirectional triode thyristor **661** in conduction.

In one embodiment, values of the parameters of the protection circuit **660** may be set as follows. The resistance of resistor **669** may be about 10 ohms. The capacitance of capacitor **670** may be about 1 nF. The capacitance of capacitor **633** may be about 10 nF. The (breakover) voltage of symmetrical trigger diode **662** may be in the range of about 26-36 volts. The resistance of resistor **671** may be in the range of about 300 k-600 k ohms, and may be, in some embodiments, about 540 k ohms. The resistance of resistor **666** is in some embodiments in the range of about 100 k-300 k ohms, and may be, in some embodiments, about 220 k ohms. The resistance of resistor **665** is in some embodiments in the range of about 30 k-100 k ohms, and may be, in some embodiments about 40 k ohms. The resistance of resistor **664** is in some embodiments in the range of about 100 k-300 k ohms, and may be, in some embodiments about 220k ohms.

FIG. **57**A is a block diagram of a power supply module in an LED lamp according to an embodiment of the present invention. Compared to FIG. **54**A, the embodiment of FIG.

57A includes two rectifying circuits **510** and **540**, a filtering circuit **520**, and a driving circuit **1530**, and further includes a mode switching circuit **580**. In this embodiment, a driving circuit **1530** and an LED module **630** compose the LED lighting module **530**. The mode switching circuit **580** is coupled to at least one of the filtering output terminals **521** and **522** and at least one of the driving output terminals **1521** and **1522**, for determining whether to perform a first driving mode or a second driving mode, as according to a frequency of the external driving signal. In the first driving mode, a filtered signal from the filtering circuit **520** is input into the driving circuit **1530**, while in the second driving mode the filtered signal bypasses at least a component of the driving circuit **1530**, making the driving circuit **1530** stop working in conducting the filtered signal, allowing the filtered signal to (directly) reach and drive the LED module **630**. The bypassed component(s) of the driving circuit **1530** may include an inductor or a switch, which when bypassed makes the driving circuit **1530** unable to transfer and/or convert power, and then stop working in conducting the filtered signal. If the driving circuit **1530** includes a capacitor, the capacitor can still be used to filter out ripples of the filtered signal in order to stabilize the voltage across the LED module. When the mode switching circuit **580** determines on performing the first driving mode, allowing the filtered signal to be input to the driving circuit **1530**, the driving circuit **1530** then transforms the filtered signal into a driving signal for driving the LED module **630** to emit light. On the other hand, when the mode switching circuit **580** determines on performing the second driving mode, allowing the filtered signal to bypass the driving circuit **1530** to reach the LED module **630**, the filtering circuit **520** becomes in effect a driving circuit for LED module **630**. Then the filtering circuit **520** provides the filtered signal as a driving signal for the LED module for driving the LED module to emit light.

It's worth noting that the mode switching circuit **580** can determine whether to perform the first driving mode or the second driving mode based on a user's instruction or a detected signal received by the LED lamp through the pins **501**, **502**, **503**, and **504**. With the mode switching circuit, the power supply module of the LED lamp can adapt to or perform one of appropriate driving modes corresponding to different application environments or driving systems, thus improving the compatibility of the LED lamp.

FIG. **57**B is a schematic diagram of the mode switching circuit in an LED lamp according to an embodiment of the present invention. Referring to FIG. **57**B, a mode switching circuit **680** includes a mode switch **681** suitable for use with the driving circuit **1630** in FIG. **54**C. Referring to FIGS. **57**B and **54**C, the mode switch **681** has three terminals **683**, **684**, and **685**, wherein the terminal **683** is coupled to the driving output terminal **1522**, the terminal **684** is coupled to the filtering output terminal **522**, and the terminal **685** is coupled to the inductor **1632** in the driving circuit **1630**.

When the mode switching circuit **680** determines on performing a first driving mode, the mode switch **681** conducts current in a first conductive path through the terminals **683** and **685** and a second conductive path through the terminals **683** and **684** is in a cutoff state. In this case, the driving output terminal **1522** is coupled to the inductor **1632**, and therefore the driving circuit **1630** is working normally, which working includes receiving a filtered signal from the filtering output terminals **521** and **522** and then transforming the filtered signal into a driving signal, output at the driving output terminals **1521** and **1522** for driving the LED module.

When the mode switching circuit **680** determines on performing a second driving mode, the mode switch **681** conducts current in the second conductive path through the terminals **683** and **684** and the first conductive path through the terminals **683** and **685** is in a cutoff state. In this case, the driving output terminal **1522** is coupled to the filtering output terminal **522**, and therefore the driving circuit **1630** stops working, and a filtered signal is input through the filtering output terminals **521** and **522** to the driving output terminals **1521** and **1522** for driving the LED module, while bypassing the inductor **1632** and the switch **1635** in the driving circuit **1630**.

FIG. **57**C is a schematic diagram of the mode switching circuit in an LED lamp according to an embodiment of the present invention. Referring to FIG. **57**C, a mode switching circuit **780** includes a mode switch **781** being suitable for use with the driving circuit **1630** in FIG. **54**C. Referring to FIGS. **57**C and **54**C, the mode switch **781** has three terminals **783**, **784**, and **785**, wherein the terminal **783** is coupled to the filtering output terminal **522**, the terminal **784** is coupled to the driving output terminal **1522**, and the terminal **785** is coupled to switch **1635** in the driving circuit **1630**.

When the mode switching circuit **780** determines on performing a first driving mode, the mode switch **781** conducts current in a first conductive path through the terminals **783** and **785** and a second conductive path through the terminals **783** and **784** is in a cutoff state. In this case, the filtering output terminal **522** is coupled to the switch **1635**, and therefore the driving circuit **1630** is working normally, which working includes receiving a filtered signal from the filtering output terminals **521** and **522** and then transforming the filtered signal into a driving signal, output at the driving output terminals **1521** and **1522** for driving the LED module.

When the mode switching circuit **780** determines on performing a second driving mode, the mode switch **781** conducts current in the second conductive path through the terminals **783** and **784** and the first conductive path through the terminals **783** and **785** is in a cutoff state. In this case, the driving output terminal **1522** is coupled to the filtering output terminal **522**, and therefore the driving circuit **1630** stops working, and a filtered signal is input through the filtering output terminals **521** and **522** to the driving output terminals **1521** and **1522** for driving the LED module, while bypassing the inductor **1632** and the switch **1635** in the driving circuit **1630**.

FIG. **57**D is a schematic diagram of the mode switching circuit in an LED lamp according to an embodiment of the present invention. Referring to FIG. **57**D, a mode switching circuit **880** includes a mode switch **881** being suitable for use with the driving circuit **1730** in FIG. **54**D. Referring to FIGS. **57**D and **54**D, the mode switch **881** has three terminals **883**, **884**, and **885**, wherein the terminal **883** is coupled to the filtering output terminal **521**, the terminal **884** is coupled to the driving output terminal **1521**, and the terminal **885** is coupled to the inductor **1732** in the driving circuit **1730**.

When the mode switching circuit **880** determines on performing a first driving mode, the mode switch **881** conducts current in a first conductive path through the terminals **883** and **885** and a second conductive path through the terminals **883** and **884** is in a cutoff state. In this case, the filtering output terminal **521** is coupled to the inductor **1732**, and therefore the driving circuit **1730** is working normally, which working includes receiving a filtered signal from the filtering output terminals **521** and **522** and then transforming the filtered signal into a driving signal, output at the driving output terminals **1521** and **1522** for driving the LED module.

When the mode switching circuit **880** determines on performing a second driving mode, the mode switch **881** conducts current in the second conductive path through the terminals **883** and **884** and the first conductive path through the terminals **883** and **885** is in a cutoff state. In this case, the driving output terminal **1521** is coupled to the filtering output terminal **521**, and therefore the driving circuit **1730** stops working, and a filtered signal is input through the filtering output terminals **521** and **522** to the driving output terminals **1521** and **1522** for driving the LED module, while bypassing the inductor **1732** and the freewheeling diode **1733** in the driving circuit **1730**.

FIG. **57**E is a schematic diagram of the mode switching circuit in an LED lamp according to an embodiment of the present invention. Referring to FIG. **57**E, a mode switching circuit **980** includes a mode switch **981** being suitable for use with the driving circuit **1730** in FIG. **54**D. Referring to FIGS. **57**E and **54**D, the mode switch **981** has three terminals **983**, **984**, and **985**, wherein the terminal **983** is coupled to the driving output terminal **1521**, the terminal **984** is coupled to the filtering output terminal **521**, and the terminal **985** is coupled to the cathode of diode **1733** in the driving circuit **1730**.

When the mode switching circuit **980** determines on performing a first driving mode, the mode switch **981** conducts current in a first conductive path through the terminals **983** and **985**, and a second conductive path through the terminals **983** and **984** is in a cutoff state. In this case, the filtering output terminal **521** is coupled to the cathode of diode **1733**, and therefore the driving circuit **1730** is working normally, which working includes receiving a filtered signal from the filtering output terminals **521** and **522** and then transforming the filtered signal into a driving signal, output at the driving output terminals **1521** and **1522** for driving the LED module.

When the mode switching circuit **980** determines on performing a second driving mode, the mode switch **981** conducts current in the second conductive path through the terminals **983** and **984** and the first conductive path through the terminals **983** and **985** is in a cutoff state. In this case, the driving output terminal **1521** is coupled to the filtering output terminal **521**, and therefore the driving circuit **1730** stops working, and a filtered signal is input through the filtering output terminals **521** and **522** to the driving output terminals **1521** and **1522** for driving the LED module, while bypassing the inductor **1732** and the freewheeling diode **1733** in the driving circuit **1730**.

FIG. **57**F is a schematic diagram of the mode switching circuit in an LED lamp according to an embodiment of the present invention. Referring to FIG. **57**F, a mode switching circuit **1680** includes a mode switch **1681** being suitable for use with the driving circuit **1830** in FIG. **54**E. Referring to FIGS. **57**F and **54**E, the mode switch **1681** has three terminals **1683**, **1684**, and **1685**, wherein the terminal **1683** is coupled to the filtering output terminal **521**, the terminal **1684** is coupled to the driving output terminal **1521**, and the terminal **1685** is coupled to switch **1835** in the driving circuit **1830**.

When the mode switching circuit **1680** determines on performing a first driving mode, the mode switch **1681** conducts current in a first conductive path through the terminals **1683** and **1685**, and a second conductive path through the terminals **1683** and **1684** is in a cutoff state. In this case, the filtering output terminal **521** is coupled to the switch **1835**, and therefore the driving circuit **1830** is working normally, which working includes receiving a filtered signal from the filtering output terminals **521** and **522** and then transforming the filtered signal into a driving signal, output at the driving output terminals **1521** and **1522** for driving the LED module.

When the mode switching circuit **1680** determines on performing a second driving mode, the mode switch **1681** conducts current in the second conductive path through the terminals **1683** and **1684** and the first conductive path through the terminals **1683** and **1685** is in a cutoff state. In this case, the driving output terminal **1521** is coupled to the filtering output terminal **521**, and therefore the driving circuit **1830** stops working, and a filtered signal is input through the filtering output terminals **521** and **522** to the driving output terminals **1521** and **1522** for driving the LED module, while bypassing the inductor **1832** and the switch **1835** in the driving circuit **1830**.

FIG. **57**G is a schematic diagram of the mode switching circuit in an LED lamp according to an embodiment of the present invention. Referring to FIG. **57**G, a mode switching circuit **1780** includes a mode switch **1781** being suitable for use with the driving circuit **1830** in FIG. **54**E. Referring to FIGS. **57**G and **54**E, the mode switch **1781** has three terminals **1783**, **1784**, and **1785**, wherein the terminal **1783** is coupled to the filtering output terminal **521**, the terminal **1784** is coupled to the driving output terminal **1521**, and the terminal **1785** is coupled to inductor **1832** in the driving circuit **1830**.

When the mode switching circuit **1780** determines on performing a first driving mode, the mode switch **1781** conducts current in a first conductive path through the terminals **1783** and **1785**, and a second conductive path through the terminals **1783** and **1784** is in a cutoff state. In this case, the filtering output terminal **521** is coupled to the inductor **1832**, and therefore the driving circuit **1830** is working normally, which working includes receiving a filtered signal from the filtering output terminals **521** and **522** and then transforming the filtered signal into a driving signal, output at the driving output terminals **1521** and **1522** for driving the LED module.

When the mode switching circuit **1780** determines on performing a second driving mode, the mode switch **1781** conducts current in the second conductive path through the terminals **1783** and **1784** and the first conductive path through the terminals **1783** and **1785** is in a cutoff state. In this case, the driving output terminal **1521** is coupled to the filtering output terminal **521**, and therefore the driving circuit **1830** stops working, and a filtered signal is input through the filtering output terminals **521** and **522** to the driving output terminals **1521** and **1522** for driving the LED module, while bypassing the inductor **1832** and the switch **1835** in the driving circuit **1830**.

FIG. **57**H is a schematic diagram of the mode switching circuit in an LED lamp according to an embodiment of the present invention. Referring to FIG. **57**H, a mode switching circuit **1880** includes two mode switches **1881** and **1882** being suitable for use with the driving circuit **1930** in FIG. **54**F. Referring to FIGS. **57**H and **54**F, the mode switch **1881** has three terminals **1883**, **1884**, and **1885**, wherein the terminal **1883** is coupled to the driving output terminal **1521**, the terminal **1884** is coupled to the filtering output terminal **521**, and the terminal **1885** is coupled to the freewheeling diode **1933** in the driving circuit **1930**. And the mode switch **1882** has three terminals **1886**, **1887**, and **1888**, wherein the terminal **1886** is coupled to the driving output terminal **1522**, the terminal **1887** is coupled to the filtering output terminal **522**, and the terminal **1888** is coupled to the filtering output terminal **521**.

When the mode switching circuit **1880** determines on performing a first driving mode, the mode switch **1881** conducts current in a first conductive path through the terminals **1883** and **1885**, and a second conductive path through the terminals **1883** and **1884** is in a cutoff state, and the mode switch **1882** conducts current in a third conductive path through the terminals **1886** and **1888**, and a fourth conductive path through the terminals **1886** and **1887** is in a cutoff state. In this case, the driving output terminal **1521** is coupled to the freewheeling diode **1933**, and the filtering output terminal **521** is coupled to the driving output terminal **1522**. Therefore the driving circuit **1930** is working normally, which working includes receiving a filtered signal from the filtering output terminals **521** and **522** and then transforming the filtered signal into a driving signal, output at the driving output terminals **1521** and **1522** for driving the LED module.

When the mode switching circuit **1880** determines on performing a second driving mode, the mode switch **1881** conducts current in the second conductive path through the terminals **1883** and **1884**, and the first conductive path through the terminals **1883** and **1885** is in a cutoff state, and the mode switch **1882** conducts current in the fourth conductive path through the terminals **1886** and **1887**, and the third conductive path through the terminals **1886** and **1888** is in a cutoff state. In this case, the driving output terminal **1521** is coupled to the filtering output terminal **521**, and the filtering output terminal **522** is coupled to the driving output terminal **1522**. Therefore the driving circuit **1930** stops working, and a filtered signal is input through the filtering output terminals **521** and **522** to the driving output terminals **1521** and **1522** for driving the LED module, while bypassing the freewheeling diode **1933** and the switch **1935** in the driving circuit **1930**.

FIG. **57**I is a schematic diagram of the mode switching circuit in an LED lamp according to an embodiment of the present invention. Referring to FIG. **57**I, a mode switching circuit **1980** includes two mode switches **1981** and **1982** being suitable for use with the driving circuit **1930** in FIG. **54**F. Referring to FIGS. **57**I and **54**F, the mode switch **1981** has three terminals **1983**, **1984**, and **1985**, wherein the terminal **1983** is coupled to the filtering output terminal **522**, the terminal **1984** is coupled to the driving output terminal **1522**, and the terminal **1985** is coupled to switch **1935** in the driving circuit **1930**. And the mode switch **1982** has three terminals **1986**, **1987**, and **1988**, wherein the terminal **1986** is coupled to the filtering output terminal **521**, the terminal **1987** is coupled to the driving output terminal **1521**, and the terminal **1988** is coupled to the driving output terminal **1522**.

When the mode switching circuit **1980** determines on performing a first driving mode, the mode switch **1981** conducts current in a first conductive path through the terminals **1983** and **1985**, and a second conductive path through the terminals **1983** and **1984** is in a cutoff state, and the mode switch **1982** conducts current in a third conductive path through the terminals **1986** and **1988**, and a fourth conductive path through the terminals **1986** and **1987** is in a cutoff state. In this case, driving output terminal **1522** is coupled to the filtering output terminal **521**, and the filtering output terminal **522** is coupled to the switch **1935**. Therefore the driving circuit **1930** is working normally, which working includes receiving a filtered signal from the filtering output terminals **521** and **522** and then transforming the filtered signal into a driving signal, output at the driving output terminals **1521** and **1522** for driving the LED module.

When the mode switching circuit **1980** determines on performing a second driving mode, the mode switch **1981** conducts current in the second conductive path through the terminals **1983** and **1984**, and the first conductive path through the terminals **1983** and **1985** is in a cutoff state, and the mode switch **1982** conducts current in the fourth conductive path through the terminals **1986** and **1987**, and the third conductive path through the terminals **1986** and **1988** is in a cutoff state. In this case, the driving output terminal **1521** is coupled to the filtering output terminal **521**, and the filtering output terminal **522** is coupled to the driving output terminal **1522**. Therefore the driving circuit **1930** stops working, and a filtered signal is input through the filtering output terminals **521** and **522** to the driving output terminals **1521** and **1522** for driving the LED module, while bypassing the freewheeling diode **1933** and the switch **1935** in the driving circuit **1930**.

It's worth noting that the mode switches in the above embodiments may each comprise, for example, a single-pole double-throw switch, or comprise two semiconductor switches (such as metal oxide semiconductor transistors), for switching a conductive path on to conduct current while leaving the other conductive path cutoff. Each of the two conductive paths provides a path for conducting the filtered signal, allowing the current of the filtered signal to flow through one of the two paths, thereby achieving the function of mode switching or selection. For example, with reference to FIG. **49**A, when the lamp driving circuit **505** is not present and the LED tube lamp **500** is directly supplied by the AC power supply **508**, the mode switching circuit may determine on performing a first driving mode in which the driving circuit transforms the filtered signal into a driving signal with a logic level meeting a required logic level to properly drive the LED module to emit light. On the other hand, when the lamp driving circuit **505** is present, the mode switching circuit may determine on performing a second driving mode in which the filtered signal is (almost) directly used to drive the LED module to emit light; or alternatively the mode switching circuit may determine on performing the first driving mode to drive the LED module to emit light.

FIG. **58**A is a block diagram of a power supply module in an LED lamp according to an embodiment of the present invention. Compared to FIG. **49**B, the embodiment of FIG. **58**A includes two rectifying circuits **510** and **540**, a filtering circuit **520**, and a driving circuit **1530**, and further includes a ballast-compatible circuit **1510**. In this embodiment, a driving circuit **1530** and an LED module **630** compose the LED lighting module **530**. The ballast-compatible circuit **1510** may be coupled between the pin **501** and/or pin **502** and the rectifying circuit **510**. This embodiment is explained assuming the ballast-compatible circuit **1510** to be coupled between the pin **501** and the rectifying circuit **510**.

In an initial stage upon the activation of the driving system of the lamp driving circuit **505**, the lamp driving circuit **505**'s ability to output relevant signal(s) has not risen to a standard state. However, in the initial stage the power supply module of the LED lamp instantly or rapidly receives or conducts the AC driving signal provided by the lamp driving circuit **505**, which initial conduction is likely to fail the starting of the LED lamp by the lamp driving circuit **505** as the lamp driving circuit **505** is initially loaded by the LED lamp in this stage. For example, the internal components of the lamp driving circuit **505** may need to retrieve power from a transformed output in the lamp driving circuit **505** in order to maintain their operation upon the activation. In this case, the activation of the lamp driving circuit **505** may end up failing as its output voltage could not normally rise to a required logic level in this initial stage; or the quality factor (Q) of a resonant circuit in the lamp driving circuit **505** may vary as a result of the initial loading from the LED lamp, so as to cause the failure of the activation.

In this embodiment, in the initial stage upon activation, the ballast-compatible circuit **1510** will be in an open-circuit state, preventing the energy of the AC driving signal from reaching the LED module. After a defined delay upon the AC driving signal as an external driving signal being input to the LED tube lamp, the ballast-compatible circuit **1510** switches from a cutoff state during the delay to a conducting state, allowing the energy of the AC driving signal to start to reach the LED module. By means of the delayed conduction of the ballast-compatible circuit **1510**, operation of the LED lamp simulates the lamp-starting characteristics of a fluorescent lamp, that is, internal gases of the fluorescent lamp will normally discharge for light emission after a delay upon activation of a driving power supply. Therefore, the ballast-compatible circuit **1510** further improves the compatibility of the LED lamp with the lamp driving circuits **505** such as an electronic ballast.

FIG. **58**B is a block diagram of a power supply module in an LED lamp according to an embodiment of the present invention. Compared to FIG. **58**A, a ballast-compatible circuit **1510** in the embodiment of FIG. **58**B is coupled between the pin **503** and/or pin **504** and the rectifying circuit **540**. As explained regarding the ballast-compatible circuit **1510** in FIG. **58**A, the ballast-compatible circuit **1510** in FIG. **58**B performs the function of delaying the starting of the LED lamp, or causing the input of the AC driving signal to be delayed for a predefined time, in order to prevent the failure of starting by the lamp driving circuits **505** such as an electronic ballast.

Apart from coupling the ballast-compatible circuit **1510** between the terminal pin(s) and the rectifying circuit in the above embodiments, the ballast-compatible circuit **1510** may alternatively be included within a rectifying circuit with a different structure. FIG. **58**C illustrates an arrangement with a ballast-compatible circuit in an LED lamp according to a preferred embodiment of the present invention. Referring to FIG. **58**C, the rectifying circuit assumes the circuit structure of the rectifying circuit **810** in FIG. **50**C. The rectifying circuit **810** includes a rectifying unit **815** and a terminal adapter circuit **541**. The rectifying unit **815** is coupled to the pins **501** and **502**, the terminal adapter circuit **541** is coupled to the output terminals **511** and **512**, and the ballast-compatible circuit **1510** in FIG. **58**C is coupled between the rectifying unit **815** and the terminal adapter circuit **541**. In this case, in the initial stage upon activation of the ballast, an AC driving signal as an external driving signal is input to the LED tube lamp, where the AC driving signal can only reach the rectifying unit **815**, but cannot reach other circuits such as the terminal adapter circuit **541**, other internal filter circuitry, and the LED lighting module. Moreover, the parasitic capacitors associated with the rectifying diodes **811** and **812** within the rectifying unit **815** are quite small in capacitance and thus can be ignored. Accordingly, the lamp driving circuit **505** in the initial stage isn't loaded with or effectively connected to the equivalent capacitor or inductor of the power supply module of the LED lamp, and the quality factor (Q) of the lamp driving circuit **505** is therefore not adversely affected in this stage, resulting in a successful starting of the LED lamp by the lamp driving circuit **505**.

It's worth noting that under the condition that the terminal adapter circuit **541** doesn't include components such as capacitors or inductors, interchanging the rectifying unit **815** and the terminal adapter circuit **541** in position, meaning the rectifying unit **815** is connected to the output terminals **511** and **512** and the terminal adapter circuit **541** is connected to the pins **501** and **502**, doesn't affect or alter the function of the ballast-compatible circuit **1510**.

Further, as explained in FIGS. **50**A-**50**D, when a rectifying circuit is connected to the pins **503** and **504** instead of the pins **501** and **502**, this rectifying circuit may constitute the rectifying circuit **540**. That is, the circuit arrangement with a ballast-compatible circuit **1510** in FIG. **58**C may be alternatively included in the rectifying circuit **540** instead of the rectifying circuit **810**, without affecting the function of the ballast-compatible circuit **1510**.

In some embodiments, as described above the terminal adapter circuit **541** doesn't include components such as capacitors or inductors. Or when the rectifying circuit **610** in FIG. **50**A constitutes the rectifying circuit **510** or **540**, the parasitic capacitances in the rectifying circuit **510** or **540** are quite small and thus can be ignored. These conditions contribute to not affecting the quality factor of the lamp driving circuit **505**.

FIG. **58**D is a block diagram of a power supply module in an LED lamp according to an embodiment of the present invention. Compared to the embodiment of FIG. **58**A, a ballast-compatible circuit **1510** in the embodiment of FIG. **58**D is coupled between the rectifying circuit **540** and the filtering circuit **520**. Since the rectifying circuit **540** also doesn't include components such as capacitors or inductors, the function of the ballast-compatible circuit **1510** in the embodiment of FIG. **58**D will not be affected.

FIG. **58**E is a block diagram of a power supply module in an LED lamp according to an embodiment of the present invention. Compared to the embodiment of FIG. **58**A, a ballast-compatible circuit **1510** in the embodiment of FIG. **58**E is coupled between the rectifying circuit **510** and the filtering circuit **520**. Similarly, since the rectifying circuit **510** doesn't include components such as capacitors or inductors, the function of the ballast-compatible circuit **1510** in the embodiment of FIG. **58**E will not be affected.

FIG. **58**F is a schematic diagram of the ballast-compatible circuit according to an embodiment of the present invention. Referring to FIG. **58**F, a ballast-compatible circuit **1610** has an initial state in which an equivalent open-circuit is obtained at the ballast-compatible circuit input and output terminals **1611** and **1621**. Upon receiving an input signal at the ballast-compatible circuit input terminal **1611**, a delay will pass until a current conduction occurs through and between the ballast-compatible circuit input and output terminals **1611** and **1621**, transmitting the input signal to the ballast-compatible circuit output terminal **1621**.

The Ballast-compatible circuit **1610** includes a diode **1612**, multiple resistors **1613**, **1615**, **1618**, **1620**, and **1622**, a bidirectional triode thyristor (TRIAC) **1614**, a DIAC or symmetrical trigger diode **1617**, a capacitor **1619**, and ballast-compatible circuit input and output terminals **1611** and **1621**. It's noted that the resistance of resistor **1613** should be quite large so that when the bidirectional triode thyristor **1614** is cutoff in an open-circuit state, an equivalent open-circuit is obtained at ballast-compatible circuit input and output terminals **1611** and **1621**.

The bidirectional triode thyristor **1614** is coupled between the ballast-compatible circuit input and output terminals **1611** and **1621**, and the resistor **1613** is also coupled between the ballast-compatible circuit input and output terminals **1611** and **1621** and in parallel to the bidirectional triode thyristor **1614**. The diode **1612**, the resistors **1620** and **1622**, and the capacitor **1619** are series-connected in sequence between the ballast-compatible circuit input and output terminals **1611** and **1621**, and are connected in parallel to the bidirectional triode thyristor **1614**. The diode **1612** has an anode connected to the bidirectional triode thyristor **1614**, and has a cathode connected to an end of the resistor **1620**. The bidirectional triode thyristor **1614** has a control terminal connected to a terminal of the symmetrical trigger diode **1617**, which has another terminal connected to an end of the resistor **1618**, which has another end connected to a node connecting the capacitor **1619** and the resistor **1622**. The resistor **1615** is connected between the control terminal of the bidirectional triode thyristor **1614** and a node connecting the resistor **1613** and the capacitor **1619**. In some embodiments, the resistors **1615**, **1618**, and **1620** could be omitted, and hence they are depicted in dotted line. When the resistor **1618** is omitted, another terminal of the symmetrical trigger diode **1617** mentioned above is directly connected to the node connecting the capacitor **1619** and the resistor **1622**. And the cathode of the diode **1612** is connected to the resistor **1622** directly when the resistor **1620** is omitted.

When an AC driving signal (such as a high-frequency high-voltage AC signal output by an electronic ballast) is initially input to the ballast-compatible circuit input terminal **1611**, the bidirectional triode thyristor **1614** will be in an open-circuit state, not allowing the AC driving signal to pass through and the LED lamp is therefore also in an open-circuit state. In this state, the AC driving signal is charging the capacitor **1619** through the diode **1612** and the resistors **1620** and **1622**, gradually increasing the voltage of the capacitor **1619**. Upon continually charging for a period of time, the voltage of the capacitor **1619** increases to be above the trigger voltage value of the symmetrical trigger diode **1617** so that the symmetrical trigger diode **1617** is turned on in a conducting state. Then the conducting symmetrical trigger diode **1617** will in turn trigger the bidirectional triode thyristor **1614** on in a conducting state. In this situation, the conducting bidirectional triode thyristor **1614** electrically connects the ballast-compatible circuit input and output terminals **1611** and **1621**, allowing the AC driving signal to flow through the ballast-compatible circuit input and output terminals **1611** and **1621**, thus starting the operation of the power supply module of the LED lamp. In this case the energy stored by the capacitor **1619** will maintain the conducting state of the bidirectional triode thyristor **1614**, to prevent the AC variation of the AC driving signal from causing the bidirectional triode thyristor **1614** and therefore the ballast-compatible circuit **1610** to be cutoff again, or to prevent or reduce the bidirectional triode thyristor **1614** alternating or switching between its conducting and cutoff states.

When the ballast-compatible circuit **1610** for the present embodiment is applied to the application circuits shown in FIGS. **58**C-**58**D, the diode **1612** could be omitted because the ballast-compatible circuit **1610** receives the signal that has rectified by the rectifying unit/circuit. In some cases, the bidirectional triode thyristor **1614** could be replaced with a silicon controlled rectifier (SCR), and the symmetrical trigger diode **1617** could be replaced with a thyristor surge suppresser. This kind of replacement does not affect the protection for the circuit. Further, using a silicon controlled rectifier instead of a bidirectional triode thyristor has a lower voltage drop across itself in conduction than that across the bidirectional triode thyristor in conduction.

In general, in hundreds of milliseconds upon activation of a lamp driving circuit **505** such as an electronic ballast, the output voltage of the ballast has risen above a certain voltage value as the output voltage hasn't been adversely affected by the sudden initial loading from the LED lamp. In some cases, the AC voltage output from some instant-start ballasts will be firstly kept at a fixed value for a short period, such as 0.01 second, and in the meanwhile, the AC voltage at the fixed value is under 300V and rises or increases with time. However, any loading added at the output of the instant-start ballast in this short period would cause the instant-start ballast failing to pull up the AC voltage for outputting, in particularly, this situation will be quite often when the input voltage of the instant-start ballast is 120V or bellow. Besides, a detection mechanism to detect whether lighting of a fluorescent lamp is achieved may be disposed in lamp driving circuits **505** such as an electronic ballast. In this detection mechanism, if a fluorescent lamp fails to be lit up for a defined period of time, an abnormal state of the fluorescent lamp is detected, causing the fluorescent lamp to enter a protection state. In view of these facts, in certain embodiments, the delay provided by the ballast-compatible circuit **1610** until conduction of the ballast-compatible circuit **1610** and then the LED lamp should be bigger than 0.01 second and may be in the range of about 0.1-3 seconds.

It's worth noting that an additional capacitor **1623** may be coupled in parallel to the resistor **1622**. The capacitor **1623** works to reflect or support instantaneous change in the voltage between the ballast-compatible circuit input and output terminals **1611** and **1621**, and will not affect the function of delayed conduction performed by the ballast-compatible circuit **1610**.

FIG. **58**G is a block diagram of a power supply module in an LED lamp according to an embodiment of the present invention. Compared to the embodiment of FIG. **49**A, the lamp driving circuit **505** in the embodiment of FIG. **58**G drives a plurality of LED tube lamps **500** connected in series, wherein a ballast-compatible circuit **1610** is disposed in each of the LED tube lamps **500**. For the convenience of illustration, two series-connected LED tube lamps **500** are assumed for example and explained as follows.

Because the two ballast-compatible circuits **1610** respectively of the two LED tube lamps **500** can actually have different delays until conduction of the LED tube lamps **500**, due to various factors such as errors occurring in production processes of some components, the actual timing of conduction of each of the ballast-compatible circuits **1610** is different. Upon activation of a lamp driving circuit **505**, the voltage of the AC driving signal provided by the lamp driving circuit **505** will be shared out by the two LED tube lamps **500** roughly equally. Subsequently when only one of the two LED tube lamps **500** first enters a conducting state, the voltage of the AC driving signal then will be borne mostly or entirely by the other LED tube lamp **500**. This situation will cause the voltage across the ballast-compatible circuits **1610** in the other LED tube lamp **500** that's not conducting to suddenly increase or be doubled, meaning the voltage between the ballast-compatible circuit input and output terminals **1611** and **1621** might even be suddenly doubled. In view of this, if the capacitor **1623** is included, the voltage division effect between the capacitors **1619** and **1623** will instantaneously increase the voltage of the capacitor **1619**, making the symmetrical trigger diode **1617** triggering the bidirectional triode thyristor **1614** into a conducting state, thus causing the two ballast-compatible circuits **1610** respectively of the two LED tube lamps **500** to become conducting almost at the same time. Therefore, by introducing the capacitor **1623**, the situation, where one of the two ballast-compatible circuits **1610** respectively of the two series-connected LED tube lamps **500** that is first conducting has its bidirectional triode thyristor **1614** then suddenly cutoff as having insufficient current passing through due to the discrepancy between the delays provided by the two ballast-compatible circuits **1610** until their respective conductions, can be avoided. Therefore, using each ballast-compatible circuit **1610** with the capacitor **1623** further improves the compatibility of the series-connected LED tube lamps with each of the lamp driving circuits **505** such as an electronic ballast.

In practical use, a suggested range for the capacitance of the capacitor **1623** is about 10 pF to about 1 nF, which may in some cases be in the range of about 10 pF to about 100 pF, and may be about 47 pF in certain embodiments.

It's worth noting that the diode **1612** is used or configured to rectify the signal for charging the capacitor **1619**. Therefore, with reference to FIGS. **58**C, **58**D, and **58**E, in the case when the ballast-compatible circuit **1610** is arranged following a rectifying unit or circuit, the diode **1612** may be omitted. Thus the diode **1612** is depicted in a dotted line in FIG. **58**F.

FIG. **58**H is a schematic diagram of the ballast-compatible circuit according to another embodiment of the present invention. Referring to FIG. **58**H, a ballast-compatible circuit **1710** has an initial state in which an equivalent open-circuit is obtained at the ballast-compatible circuit input and output terminals **1711** and **1721**. Upon receiving an input signal at the ballast-compatible circuit input terminal **1711**, the ballast-compatible circuit **1710** will be in a cutoff state when the logic level of the input external driving signal is below a defined value corresponding to a conduction delay of the ballast-compatible circuit **1710**; and the ballast-compatible circuit **1710** will enter a conducting state upon the logic level of the input external driving signal reaching the defined value, thus transmitting the input signal to the ballast-compatible circuit output terminal **1721**. In some cases, the defined value is equal to or bigger than 400V.

The ballast-compatible circuit **1710** includes a bidirectional triode thyristor (TRIAC) **1712**, a DIAC or symmetrical trigger diode **1713**, multiple resistors **1714**, **1716**, and **1717**, and a capacitor **1715**. The bidirectional triode thyristor **1712** has a first terminal connected to the ballast-compatible circuit input terminal **1711**; a control terminal connected to a terminal of the symmetrical trigger diode **1713** and an end of the resistor **1714**; and a second terminal connected to another end of the resistor **1714**. The capacitor **1715** has an end connected to another terminal of the symmetrical trigger diode **1713**, and has another end connected to the second terminal of the bidirectional triode thyristor **1712**. The resistor **1717** is in parallel connection with the capacitor **1715**, and is therefore also connected to another terminal of the symmetrical trigger diode **1713** and the second terminal of the bidirectional triode thyristor **1712** mentioned above. And the resistor **1716** has an end connected to the node connecting the capacitor **1715** and the symmetrical trigger diode **1713**, and has another end connected to the ballast-compatible circuit output terminal **1721**.

When an AC driving signal (such as a high-frequency high-voltage AC signal output by an electronic ballast) is initially input to the ballast-compatible circuit input terminal **1711**, the bidirectional triode thyristor **1712** will be in an open-circuit state, not allowing the AC driving signal to pass through and the LED lamp is therefore also in an open-circuit state. The input of the AC driving signal causes a potential difference between the ballast-compatible circuit input terminal **1711** and the ballast-compatible circuit output terminal **1721**. When the AC driving signal increases with time to eventually reach a sufficient amplitude (which is a defined logic level after the delay) after a period of time, the signal logic level at the ballast-compatible circuit output terminal **1721** has a reflected voltage at the control terminal of the bidirectional triode thyristor **1712** after passing through the resistor **1716**, the parallel-connected capacitor **1715** and the resistor **1717**, and the resistor **1714**, wherein the reflected voltage then triggers the bidirectional triode thyristor **1712** into a conducting state. This conducting state makes the ballast-compatible circuit **1710** entering a conducting state which causes the LED lamp to operate normally. Upon the bidirectional triode thyristor **1712** conducting, a current flows through the resistor **1716** and then charges the capacitor **1715** to store a specific voltage on the capacitor **1715**. In this case, the energy stored by the capacitor **1715** will maintain the conducting state of the bidirectional triode thyristor **1712**, to prevent the AC variation of the AC driving signal from causing the bidirectional triode thyristor **1712** (or the ballast-compatible circuit **1710**) to be cutoff again, or to prevent the situation of the bidirectional triode thyristor **1712** alternating or switching between its conducting and cutoff states.

FIG. **58**I illustrates the ballast-compatible circuit according to an embodiment of the present invention. Referring to FIG. **58**I, a ballast-compatible circuit **1810** includes a housing **1812**, a metallic electrode **1813**, a bimetallic strip **1814**, and a heating filament **1816**. The metallic electrode **1813** and the heating filament **1816** protrude from the housing **1812**, so that they each have a portion inside the housing **1812** and a portion outside of the housing **1812**. The metallic electrode **1813**'s outside portion has a ballast-compatible circuit input terminal **1811**, and the heating filament **1816**'s outside portion has a ballast-compatible circuit output terminal **1821**. The housing **1812** is hermetic or tightly sealed and contains inertial gas **1815** such as helium gas. The bimetallic strip **1814** is inside the housing **1812** and is physically and electrically connected to the portion of heating filament **1816** that is inside the housing **1812**. And there is a spacing between the bimetallic strip **1814** and the metallic electrode **1813**, so that the ballast-compatible circuit input terminal **1811** and the ballast-compatible circuit output terminal **1821** are not electrically connected in the initial state of the ballast-compatible circuit **1810**. The bimetallic strip **1814** may include two metallic strips with different temperature coefficients, wherein the metallic strip closer to the metallic electrode **1813** has a smaller temperature coefficient, and the metallic strip more away from the metallic electrode **1813** has a larger temperature coefficient.

When an AC driving signal (such as a high-frequency high-voltage AC signal output by an electronic ballast) is initially input at the ballast-compatible circuit input terminal **1811** and the ballast-compatible circuit output terminal **1821**, a potential difference between the metallic electrode **1813** and the heating filament **1816** is formed. When the potential difference increases enough to cause electric arc or arc discharge through the inertial gas **1815**, meaning when the AC driving signal increases with time to eventually reach the defined logic level after a delay, then the inertial gas **1815** is then heated to cause the bimetallic strip **1814** to swell toward the metallic electrode **1813** (as in the direction of the broken-line arrow in FIG. **58**I), with this swelling eventually causing the bimetallic strip **1814** to bear against or close to the metallic electrode **1813**, forming the physical and electrical connections between them. In this situation, there is electrical conduction between the ballast-compatible circuit input terminal **1811** and the ballast-compatible circuit output terminal **1821**. Then the AC driving signal flows through and thus heats the heating filament **1816**. In this heating process, the heating filament **1816** allows a current to flow through when electrical conduction exists between the metallic electrode **1813** and the bimetallic strip **1814**, causing the temperature of the bimetallic strip **1814** to be above a defined conduction temperature. As a result, since the respective temperature of the two metallic strips of the bimetallic strip **1814** with different temperature coefficients are maintained above the defined conduction temperature, the bimetallic strip **1814** will bend against or toward the metallic electrode **1813**, thus maintaining or supporting the physical joining or connection between the bimetallic strip **1814** and the metallic electrode **1813**. Therefore, upon receiving an input signal at the ballast-compatible circuit input and output terminals **1811** and **1821**, a delay will pass until an electrical/current conduction occurs through and between the ballast-compatible circuit input and output terminals **1811** and **1821**.

Therefore, an exemplary ballast-compatible circuit such as described herein may be coupled between any pin and any rectifying circuit described above in the invention, wherein the ballast-compatible circuit will be in a cutoff state in a defined delay upon an external driving signal being input to the LED tube lamp, and will enter a conducting state after the delay. Otherwise, the ballast-compatible circuit will be in a cutoff state when the logic level of the input external driving signal is below a defined value corresponding to a conduction delay of the ballast-compatible circuit; and the ballast-compatible circuit will enter a conducting state upon the logic level of the input external driving signal reaching the defined value. Accordingly, the compatibility of the LED tube lamp described herein with the lamp driving circuits **505** such as an electronic ballast is further improved by using such a ballast-compatible circuit.

FIG. **59**A is a block diagram of a power supply module in an LED tube lamp according to an embodiment of the present invention. Compared to that shown in FIG. **49**B, the present embodiment comprises two rectifying circuits **510** and **540**, a filtering circuit **520**, and a driving circuit **1530**, and further comprises two ballast-compatible circuits **1540**. In this embodiment, a driving circuit **1530** and an LED module **630** compose the LED lighting module **530**. The two ballast-compatible circuits **1540** are coupled respectively between the pin **503** and the rectifying output terminal **511** and between the pin **504** and the rectifying output terminal **511**. Referring to FIG. **49**A, the lamp driving circuit **505** is an electronic ballast for supplying an AC driving signal to drive the LED lamp of the present invention.

Two ballast-compatible circuits **1540** are initially in conducting states, and then enter into cutoff states in a delay. Therefore, in an initial stage upon activation of the lamp driving circuit **505**, the AC driving signal is transmitted through the pin **503**, the corresponding ballast-compatible circuit **1540**, the rectifying output terminal **511** and the rectifying circuit **510**, or through the pin **504**, the corresponding ballast-compatible circuit **1540**, the rectifying output terminal **511** and the rectifying circuit **510** of the LED lamp, and the filtering circuit **520** and the LED lighting module **530** of the LED lamp are bypassed. Thereby, the LED lamp presents almost no load and does not affect the quality factor of the lamp driving circuit **505** at the beginning, and so the lamp driving circuit can be activated successfully. The two ballast-compatible circuits **1540** are cut off after a time period while the lamp driving circuit **505** has been activated successfully. After that, the lamp driving circuit **505** has a sufficient drive capability for driving the LED lamp to emit light.

FIG. **59**B is a block diagram of a power supply module in an LED tube lamp according to an embodiment of the present invention. Compared to that shown in FIG. **59**A, two ballast-compatible circuits **1540** are changed to be coupled respectively between the pin **503** and the rectifying output terminal **512** and between the pin **504** and the rectifying output terminal **512**. Similarly, two ballast-compatible circuits **1540** are initially in conducting states, and then changed to cutoff states after an objective delay. Thereby, the lamp driving circuit **505** drives the LED lamp to emit light after the lamp driving circuit **505** has activated.

It is worth noting that the arrangement of the two ballast-compatible circuits **1540** may be changed to be coupled between the pin **501** and the rectifying terminal **511** and between the pin **502** and the rectifying terminal **511**, or between the pin **501** and the rectifying terminal **512** and between the pin **502** and the rectifying terminal **512**, for having the lamp driving circuit **505** drive the LED lamp to emit light after being activated.

FIG. **59**C is a block diagram of a power supply module in an LED tube lamp according to an embodiment of the present invention. Compared to that shown in FIGS. **59**A and **59**B, the rectifying circuit **810** shown in FIG. **50**C replaces the rectifying circuit **540**, and the rectifying unit **815** of the rectifying circuit **810** is coupled to the pins **503** and **504** and the terminal adapter circuit **541** thereof is coupled to the rectifying output terminals **511** and **512**. The arrangement of the two ballast-compatible circuits **1540** is also changed to be coupled respectively between the pin **501** and the half-wave node **819** and between the pin **502** and the half-wave node **819**.

In an initial stage upon activation of the lamp driving circuit **505**, two ballast-compatible circuits **1540** are initially in conducting states. At this moment, the AC driving signal is transmitted through the pin **501**, the corresponding ballast-compatible circuit **1540**, the half-wave node **819** and the rectifying unit **815**, or the pin **502**, the corresponding ballast-compatible circuit **1540**, the half-wave node **819** and the rectifying unit **815** of the LED lamp, and the terminal adapter circuit **541**, the filtering circuit **520** and the LED lighting module **530** of the LED lamp are bypassed. Thereby, the LED lamp presents almost no load and does not affect the quality factor of the lamp driving circuit **505** at the beginning, and so the lamp driving circuit can be activated successfully. The two ballast-compatible circuits **1540** are cut off after a time period while the lamp driving circuit **505** has been activated successfully. After that, the lamp driving circuit **505** has a sufficient drive capability for driving the LED lamp to emit light.

It is worth noting that the rectifying circuit **810** shown in FIG. **50**C may replace the rectifying circuit **510** of the present embodiment shown in FIG. **59**C. Wherein, the rectifying unit **815** of the rectifying circuit **810** is coupled to the pins **501** and **502** and the terminal adapter circuit **541** thereof is coupled to the rectifying output terminals **511** and **512**. The arrangement of the two ballast-compatible circuits **1540** is also changed to be coupled respectively between the pin **503** and the half-wave node **819** and between the pin **504** and the half-wave node **819**. Accordingly, the ballast-compatible circuit **1540** can still make the lamp driving circuit **505** drive the LED lamp to emit light after being activated.

FIG. **59**D is a schematic diagram of a ballast-compatible circuit according to an embodiment of the present invention, which is applicable to the embodiments shown in FIGS. **59**A and **59**C and the described modification thereof.

A ballast-compatible circuit **1640** comprises multiple resistors **1643**, **1645**, **1648** and **1650**, two capacitors **1644** and **1649**, two diodes **1647** and **1652**, two bipolar junction transistors (BJT) **1646** and **1651**, a ballast-compatible circuit terminal **1641** and a ballast-compatible circuit terminal

1642. One end of the resistor **1645** is coupled to the ballast-compatible circuit terminal **1641**, and the other end is coupled to an emitter of the BJT **1646**. A collector of the BJT **1646** is coupled to a positive end of the diode **1647**, and a negative end thereof is coupled to the ballast-compatible circuit terminal **1642**. The resistor **1643** and the capacitor **1644** are connected in series with each other and coupled between the emitter and the collector of the BJT **1646**, and the connection node of the resistor **1643** and the capacitor **1644** is coupled to a base of the BJT **1646**. One end of the resistor **1650** is coupled to the ballast-compatible circuit terminal **1642**, and the other end is coupled to an emitter of the BJT **1651**. A collector of the BJT **1651** is coupled to a positive end of the diode **1652**, and a negative end thereof is coupled to the ballast-compatible circuit terminal **1641**. The resistor **1648** and the capacitor **1649** are connected in series with each other and coupled between the emitter and the collector of the BJT **1651**, and the connection node of the resistor **1648** and the capacitor **1649** is coupled to a base of the BJT **1651**.

In an initial stage upon the lamp driving circuit **505**, e.g. electronic ballast, being activated, voltages across the capacitors **1644** and **1649** are about zero. At this time, the BJTs **1646** and **1651** are in conducting state and the bases thereof allow currents to flow through. Therefore, in an initial stage upon activation of the lamp driving circuit **505**, the ballast-compatible circuits **1640** are in conducting state. The AC driving signal charges the capacitor **1644** through the resistor **1643** and the diode **1647**, and charges the capacitor **1649** through the resistor **1648** and the diode **1652**. After a time period, the voltages across the capacitors **1644** and **1649** reach certain voltages so as to reduce the voltages of the resistors **1643** and **1648**, thereby cutting off the BJTs **1646** and **1651**, i.e., the states of the BJTs **1646** and **1651** are cutoff states. At this time, the state of the ballast-compatible circuit **1640** is changed to the cutoff state. Thereby, the internal capacitor(s) and inductor(s) do not affect in Q-factor of the lamp driving circuit **505** at the beginning for ensuring the lamp driving circuit activating. Hence, the ballast-compatible circuit **1640** improves the compatibility of LED lamp with the electronic ballast.

In summary, the two ballast-compatible circuits of the present invention are respectively coupled between a connection node of the rectifying circuit and the filtering circuit (i.e., the rectifying output terminal **511** or **512**) and the pin **501** and between the connection node and the pin **502**, or coupled between the connection node and the pin **503** and the connection node and the pin **504**. The two ballast-compatible circuits conduct for an objective delay upon the external driving signal being input into the LED tube lamp, and then are cut off after the objective delay for enhancing the compatibility of the LED lamp with the electronic ballast.

FIG. **60**A is a block diagram of a power supply module in an LED tube lamp according to an embodiment of the present invention. Compared to that shown in FIG. **49**B, the LED tube lamp comprises two rectifying circuits **510** and **540**, a filtering circuit **520**, and an LED lighting module **530**, and further comprises two filament-simulating circuits **1560**. The filament-simulating circuits **1560** are respectively coupled between the pins **501** and **502** and coupled between the pins **503** and **504**, for improving a compatibility with a lamp driving circuit having filament detection function, e.g.: program-start ballast.

In an initial stage upon the lamp driving circuit having filament detection function being activated, the lamp driving circuit will determine whether the filaments of the lamp operate normally or are in an abnormal condition of short-circuit or open-circuit. Once determining the abnormal condition of the filaments, the lamp driving circuit stops operating and enters a protection state. In order to avoid a situation where the lamp driving circuit erroneously determines the LED tube lamp to be abnormal due to the LED tube lamp having no filament, the two filament-simulating circuits **1560** simulate the operation of actual filaments of a fluorescent tube to have the lamp driving circuit enter into a normal state to start the LED lamp normally.

FIG. **60**B is a schematic diagram of a filament-simulating circuit according to an embodiment of the present invention. The filament-simulating circuit comprises a capacitor **1663** and a resistor **1665** connected in parallel, and two ends of the capacitor **1663** and two ends of the resistor **1665** are re respectively coupled to the filament simulating terminals **1661** and **1662**. Referring to FIG. **60**A, the filament simulating terminals **1661** and **1662** of the two filament simulating circuits **1660** are respectively coupled to the pins **501** and **502** and the pins **503** and **504**. During the filament detection process, the lamp driving circuit outputs a detection signal to detect the state of the filaments. The detection signal passes the capacitor **1663** and the resistor **1665** and so the lamp driving circuit determines that the filaments of the LED lamp are normal.

In addition, a capacitance value of the capacitor **1663** is low and so a capacitive reactance (equivalent impedance) of the capacitor **1663** is far lower than an impedance of the resistor **1665** due to the lamp driving circuit outputting a high-frequency alternative current (AC) signal to drive LED lamp. Therefore, the filament-simulating circuit **1660** consumes fairly low power when the LED lamp operates normally, and so it almost does not affect the luminous efficiency of the LED lamp.

FIG. **60**C is a schematic block diagram including a filament-simulating circuit according to an embodiment of the present invention. In the present embodiment, the filament-simulating circuit **1660** replaces the terminal adapter circuit **541** of the rectifying circuit **810** shown in FIG. **50**C, which is adopted as the rectifying circuit(s) **510** or/and **540** in the LED lamp. For example, the filament-simulating circuit **1660** of the present embodiment has both of filament simulating and terminal adapting functions. Referring to FIG. **60**A, the filament simulating terminals **1661** and **1662** of the filament-simulating circuit **1660** are respectively coupled to the pins **501** and **502** or/and pins **503** and **504**. The half-wave node **819** of the rectifying unit **815** in the rectifying circuit **810** is coupled to the filament simulating terminal **1662**.

FIG. **60**D is a schematic block diagram including a filament-simulating circuit according to another embodiment of the present invention. Compared to that shown in FIG. **60**C, the half-wave node is changed to be coupled to the filament simulating terminal **1661**, and the filament-simulating circuit **1660** in the present embodiment still has both of filament simulating and terminal adapting functions.

FIG. **60**E is a schematic diagram of a filament-simulating circuit according to another embodiment of the present invention. A filament-simulating circuit **1760** comprises two capacitors **1763** and **1764**, and two resistors **1765** and **1766**. The capacitors **1763** and **1764** are connected in series and coupled between the filament simulating terminals **1661** and **1662**. The resistors **1765** and **1766** are connected in series and coupled between the filament simulating terminals **1661** and **1662**. Furthermore, the connection node of the capacitors **1763** and **1764** is coupled to that of the resistors **1765** and **1766**. Referring to FIG. **60**A, the filament simulating terminals **1661** and **1662** of the filament-simulating circuit **1760** are respectively coupled to the pins **501** and **502** and the pins **503** and **504**. When the lamp driving circuit outputs the detection signal for detecting the state of the filament, the detection signal passes the capacitors **1763** and **1764** and the resistors **1765** and **1766** so that the lamp driving circuit determines that the filaments of the LED lamp are normal.

It is worth noting that in some embodiments, capacitance values of the capacitors **1763** and **1764** are low and so a capacitive reactance of the serially connected capacitors **1763** and **1764** is far lower than an impedance of the serially connected resistors **1765** and **1766** due to the lamp driving circuit outputting the high-frequency AC signal to drive LED lamp. Therefore, the filament-simulating circuit **1760** consumes fairly low power when the LED lamp operates normally, and so it almost does not affect the luminous efficiency of the LED lamp. Moreover, any one of the capacitor **1763** and the resistor **1765** is short circuited or is an open circuit, or any one of the capacitor **1764** and the resistor **1766** is short circuited or is an open circuit, the detection signal still passes through the filament-simulating circuit **1760** between the filament simulating terminals **1661** and **1662**. Therefore, the filament-simulating circuit **1760** still operates normally when any one of the capacitor **1763** and the resistor **1765** is short circuited or is an open circuit or any one of the capacitor **1764** and the resistor **1766** is short circuited or is an open circuit, and so it has quite high fault tolerance.

The embodiment of filament-simulating circuit mentioned above could use ceramic capacitor or metallized polypropylene film capacitor, such as the ceramic capacitor in class **2**, the metallized polypropylene film capacitor(X**2**). When the metallized polypropylene film capacitor(X**2**) is adopted, since its capacitance is smaller than 100 nF and it has a small inherent impedance, it can make the current of the filament-simulating circuit down to tens mA to reduce power consumption. Also, the heating caused by the inherent impedance is smaller, the temperature could be above 70 degrees Celsius or even in the range of 50-60 degrees Celsius.

In some cases, the circuit design adopts the flexible sheet to make all of or some of the LED components and the active/passive parts of the AC power module being able to be disposed on the same flexible sheet or different flexible sheets to simplify the structure design in the LED lamp. The capacitor(s) may be preferable to, for example, X7R multi-layer ceramic capacitor and the capacitance thereof can in some embodiments be bigger than 100 nF.

FIG. **60**F is a schematic block diagram including a filament-simulating circuit according to an embodiment of the present invention. In the present embodiment, the filament-simulating circuit **1860** replaces the terminal adapter circuit **541** of the rectifying circuit **810** shown in FIG. **50**C, which is adopted as the rectifying circuit **510** or/and **540** in the LED lamp. For example, the filament-simulating circuit **1860** of the present embodiment has both of filament simulating and terminal adapting functions. An impedance of the filament-simulating circuit **1860** has a negative temperature coefficient (NTC), i.e., the impedance at a higher temperature is lower than that at a lower temperature. In the present embodiment, the filament-simulating circuit **1860** comprises two NTC resistors **1863** and **1864** connected in series and coupled to the filament simulating terminals **1661** and **1662**. Referring to FIG. **60**A, the filament simulating terminals **1661** and **1662** are respectively coupled to the pins **501** and **502** or/and the pins **503** and **504**. The half-wave node **819** of the rectifying unit **815** in the rectifying circuit **810** is coupled to a connection node of the NTC resistors **1863** and **1864**.

When the lamp driving circuit outputs the detection signal for detecting the state of the filament, the detection signal passes the NTC resistors **1863** and **1864** so that the lamp driving circuit determines that the filaments of the LED lamp are normal. The impedance of the serially connected NTC resistors **1863** and **1864** is gradually decreased with the gradually increasing of temperature due to the detection signal or a preheat process. When the lamp driving circuit enters into the normal state to start the LED lamp normally, the impedance of the serially connected NTC resistors **1863** and **1864** is decreased to a relative low value and so the power consumption of the filament simulation circuit **1860** is lower.

An exemplary impedance of the filament-simulating circuit **1860** can be 10 ohms or more at room temperature (25 degrees Celsius) and may be decreased to a range of about 2-10 ohms when the lamp driving circuit enters into the normal state. It may be preferred that the impedance of the filament-simulating circuit **1860** is decreased to a range of about 3-6 ohms when the lamp driving circuit enters into the normal state.

FIG. **61**A is a block diagram of a power supply module in an LED tube lamp according to an embodiment of the present invention. Compared to that shown in FIG. **49**B, the present embodiment comprises two rectifying circuits **510** and **540**, a filtering circuit **520**, and an LED lighting module **530**, and further comprises an over voltage protection (OVP) circuit **1570**. The OVP circuit **1570** is coupled to the filtering output terminals **521** and **522** for detecting the filtered signal. The OVP circuit **1570** clamps the logic level of the filtered signal when determining the logic level thereof higher than a defined OVP value. Hence, the OVP circuit **1570** protects the LED lighting module **530** from damage due to an OVP condition.

FIG. **61**B is a schematic diagram of an overvoltage protection (OVP) circuit according to an embodiment of the present invention. An OVP circuit **1670** comprises a voltage clamping diode **1671**, such as zener diode, coupled to the filtering output terminals **521***a* nd **522**. The voltage clamping diode **1671** is conducted to clamp a voltage difference at a breakdown voltage when the voltage difference of the filtering output terminals **521** and **522** (i.e., the logic level of the filtered signal) reaches the breakdown voltage. The breakdown voltage may be preferred in a range of about 40 V to about 100 V, and more preferred in a range of about 55 V to about 75V.

FIG. **62**A is a block diagram of a power supply module in an LED tube lamp according to an embodiment of the present invention. Compared to that shown in FIG. **60**A, the present embodiment comprises two rectifying circuits **510** and **540**, a filtering circuit **520**, an LED lighting module **530** and two filament-simulating circuits **1560**, and further comprises a ballast detection circuit **1590**. The ballast detection circuit **1590** may be coupled to any one of the pins **501**, **502**, **503** and **504** and a corresponding rectifying circuit of the rectifying circuits **510** and **540**. In the present embodiment, the ballast detection circuit **1590** is coupled between the pin **501** and the rectifying circuit **510**.

The ballast detection circuit **1590** detects the AC driving signal or a signal input through the pins **501**, **502**, **503** and **504**, and determines whether the input signal is provided by an electric ballast based on the detected result.

FIG. **62**B is a block diagram of a power supply module in an LED tube lamp according to an embodiment of the present invention. Compared to that shown in FIG. **62**A, the rectifying circuit **810** shown in FIG. **50**C replaces the rectifying circuit **540** in the present embodiment. The ballast detection circuit **1590** is coupled between the rectifying unit **815** and the terminal adapter circuit **541**. One of the rectifying unit **815** and the terminal adapter circuit **541** is coupled to the pins **503** and **504**, and the other one is coupled to the rectifying output terminals **511** and **512**. In the present embodiment, the rectifying unit **815** is coupled to the pins **503** and **504**, and the terminal adapter circuit **541** is coupled to the rectifying output terminals **511** and **512**. Similarly, the ballast detection circuit **1590** detects the signal input through the pins **503** and **504** for determining the input signal whether provided by an electric ballast according to the frequency of the input signal.

In addition, the rectifying circuit **810** may replace the rectifying circuit **510** instead of the rectifying circuit **540**, and the ballast detection circuit **1590** is coupled between the rectifying unit **815** and the terminal adapter circuit **541** in the rectifying circuit **510**.

FIG. **62**C is a block diagram of a ballast detection circuit according to an embodiment of the present invention. A ballast detection circuit **1590** comprises a detection circuit **1590***a* and a switch circuit **1590***b*. The switch circuit **1590***b* is coupled to two switch terminals **1591** and **1592**. The detection circuit **1590***a* is coupled to two detection terminals **1593** and **1594** for detecting a signal transmitted through the detection terminals **1593** and **1594**. Alternatively, the switch terminals **1591** and **1592** serves as the detection terminals and the detection terminals **1593** and **1594** are omitted. For example, in certain embodiments, the switch circuit **1590***b* and the detection circuit **1590***a* are commonly coupled to the switch terminals **1591** and **1592**, and the detection circuit **1590***a* detects a signal transmitted through the switch terminals **1591** and **1592**. Hence, the detection terminals **1593** and **1594** are depicted by dotted lines.

FIG. **62**D is a schematic diagram of a ballast detection circuit according to an embodiment of the present invention. A ballast detection circuit **1690** comprises a detection circuit **1690***a* and a switch circuit **1690***b*, and is coupled between the switch terminals **1591** and **1592**. The detection circuit **1690***a* comprises a symmetrical trigger diode **1691**, two resistors **1692** and **1696** and multiple capacitors **1693**, **1697** and **1698**. The switch circuit **1690***b* comprises a TRIAC **1699** and an inductor **1694**.

The capacitor **1698** is coupled between the switch terminals **1591** and **1592** for generating a detection voltage in response to a signal transmitted through the switch terminals **1591** and **1592**. When the signal is a high frequency signal, the capacitive reactance of the capacitor **1698** is fairly low and so the detection voltage generated thereby is quite small. Whereas the signal is a low frequency signal or a DC signal, the capacitive reactance of the capacitor **1698** is quite high and so the detection voltage generated thereby is quite high. The resistor **1692** and the capacitor **1693** are connected in series and coupled between two ends of the capacitor **1698**. The serially connected resistor **1692** and the capacitor **1693** is used to filter the detection signal generated by the capacitor **1698** and generates a filtered detection signal at a connection node thereof. The filter function of the resistor **1692** and the capacitor **1693** is used to filter high frequency noise in the detection signal for preventing the switch circuit **1690***b* from misoperation due to the high frequency noise. The resistor **1696** and the capacitor **1697** are connected in series and coupled between two ends of the capacitor **1693**, and transmit the filtered detection signal to one end of the symmetrical trigger diode**1691**. The serially connected resistor **1696** and capacitor **1697** performs second filtering of the filtered detection signal to enhance the filter effect of the detection circuit **1690***a*. Based on requirement for filtering logic levels of different applications, the capacitor **1697** may be omitted and the end of the symmetrical trigger diode **1691** is coupled to the connection node of the resistor **1692** and the capacitor **1693** through the resistor **1696**. Alternatively, both of the resistor **1696** and the capacitor **1697** are omitted and the end of the symmetrical trigger diode **1691** is directly coupled to the connection node of the resistor **1692** and the capacitor **1693**. Therefore, the resistor **1696** and the capacitor **1697** are depicted by dotted lines. The other end of the symmetrical trigger diode **1691** is coupled to a control end of the TRIAC **1699** of the switch circuit **1690***b*. The symmetrical trigger diode **1691** determines whether to generate a control signal **1695** to trigger the TRIAC **1699** on according to a logic level of a received signal. A first end of the TRIAC **1699** is coupled to the switch terminal **1591** and a second end thereof is coupled to the switch terminal **1592** through the inductor **1694**. The inductor **1694** is used to protect the TRIAC **1699** from damage due to a situation where the signal transmitted into the switch terminals **1591** and **1592** is over a maximum rate of rise of commutation voltage or switching voltage, a repetitive peak voltage in off-state or a maximum rate of change of current.

When the switch terminals **1591** and **1592** receive a low frequency signal or a DC signal, the detection signal generated by the capacitor **1698** is high enough to make the symmetrical trigger diode **1691** generate the control signal **1695** to trigger the TRIAC **1699** on. At this time, the switch terminals **1591** and **1592** are shorted to bypass the circuit(s) connected in parallel with the switch circuit **1690***b*, such as a circuit coupled between the switch terminals **1591** and **1592**, the detection circuit **1690***a* and the capacitor **1698**.

In some embodiments, when the switch terminals **1591** and **1592** receive a high frequency AC signal, the detection signal generated by the capacitor **1698** is not high enough to make the symmetrical trigger diode **1691** generate the control signal **1695** to trigger the TRIAC **1699** on. At this time, the TRIAC **1699** is cut off and so the high frequency AC signal is mainly transmitted through an external circuit or the detection circuit **1690***a*.

Hence, the ballast detection circuit **1690** can determine whether the input signal is a high frequency AC signal provided by an electric ballast. If yes, the high frequency AC signal is transmitted through the external circuit or the detection circuit **1690***a*; if no, the input signal is transmitted through the switch circuit **1690***b*, bypassing the external circuit and the detection circuit **1690***a*.

It is worth noting that the capacitor **1698** may be replaced by external capacitor(s), such as at least one capacitor in the terminal adapter circuits shown in FIG. **51**A-C. Therefore, the capacitor **1698** may be omitted and be therefore depicted by a dotted line.

FIG. **62**E is a schematic diagram of a ballast detection circuit according to an embodiment of the present invention. A ballast detection circuit **1790** comprises a detection circuit **1790***a* and a switch circuit **1790***b*. The switch circuit **1790***b* is coupled between the switch terminals **1591** and **1592**. The detection circuit **1790***a* is coupled between the detection terminals **1593** and **1594**. The detection circuit **1790***a* comprises two inductors **1791** and **1792** with mutual induction, two capacitors **1793** and **1796**, a resistor **1794** and a diode **1797**. The switch circuit **1790***b* comprises a switch **1799**. In the present embodiment, the switch **1799** is a p-type depletion mode MOSFET, which is cut off when the gate voltage is higher than a threshold voltage and is conducted when the gate voltage is lower than the threshold voltage.

The inductor **1792** is coupled between the detection terminals **1593** and **1594** and induces a detection voltage in the inductor **1791** based on a current signal flowing through the detection terminals **1593** and **1594**. The logic level of the detection voltage is varied with the frequency of the current signal, and may be increased with the increasing of that frequency and reduced with the decreasing of that frequency.

In some embodiments, when the signal is a high frequency signal, the inductive reactance of the inductor **1792** is quite high and so the inductor **1791** induces the detection voltage with a quite high logic level. When the signal is a low frequency signal or a DC signal, the inductive reactance of the inductor **1792** is quite low and so the inductor **1791** induces the detection voltage with a quite low logic level. One end of the inductor **1791** is grounded. The serially connected capacitor **1793** and resistor **1794** is connected in parallel with the inductor **1791** to receive the detection voltage generated by the inductor **1791** and to filter a high frequency component of the detection voltage to generate a filtered detection voltage. The filtered detection voltage charges the capacitor **1796** through the diode **1797** to generate a control signal **1795**. Due to the diode **1797** providing a one-way charge for the capacitor **1796**, the logic level of control signal **1795** generated by the capacitor **1796** is the maximum value of the detection voltage. The capacitor **1796** is coupled to the control end of the switch **1799**. First and second ends of the switch **1799** are respectively coupled to the switch terminals **1591** and **1592**.

When the signal received by the detection terminals **1593** and **1594** is a low frequency signal or a DC signal, the control signal **1795** generated by the capacitor **1796** is lower than the threshold voltage of the switch **1799** and so the switch **1799** are conducted. At this time, the switch terminals **1591** and **1592** are shorted to bypass the external circuit(s) connected in parallel with the switch circuit **1790*b***, such as at least one capacitor in the terminal adapter circuits those shown in FIGS. **51**A-C.

When the signal received by the detection terminal **1593** and **1594** is a high frequency signal, the control signal **1795** generated by the capacitor **1796** is higher than the threshold voltage of the switch **1799** and so the switch **1799** are cut off. At this time, the high frequency signal is transmitted by the external circuit(s).

Hence, the ballast detection circuit **1790** can determine whether the input signal is a high frequency AC signal provided by an electric ballast. If yes, the high frequency AC signal is transmitted through the external circuit(s); if no, the input signal is transmitted through the switch circuit **1790*b***, bypassing the external circuit(s).

Next, exemplary embodiments of the conduction (bypass) and cut off (not bypass) operations of the switch circuit in the ballast detection circuit of an LED lamp will be illustrated. For example, the switch terminals **1591** and **1592** are coupled to a capacitor connected in series with the LED lamp, e.g., a signal for driving the LED lamp also flows through the capacitor. The capacitor may be disposed inside the LED lamp to be connected in series with internal circuit(s) or outside the LED lamp to be connected in series with the LED lamp. When the lamp driving circuit **505** exists, the lamp driving circuit **505** provides a high voltage and high frequency AC driving signal as an external driving signal to drive the LED tube lamp **500**. At this moment, the switch circuit of the ballast detection circuit is cut off, and so the capacitor is connected in series with an equivalent capacitor of the internal circuit(s) of the LED tube lamp for forming a capacitive voltage divider network. Thereby, a division voltage applied in the internal circuit(s) of the LED tube lamp is lower than the high voltage and high frequency AC driving signal, e.g.: the division voltage is in a range of

100-270V, and so no over voltage causes the internal circuit (s) damage. Alternatively, the switch terminals **1591** and **1592** is coupled to the capacitor(s) of the terminal adapter circuit shown in FIGS. **51**A-C to have the signal flowing through the half-wave node as well as the capacitor(s), e.g., the capacitor **642** in FIG. **51**A, or the capacitor **842** in FIG. **51**C. When the high voltage and high frequency AC signal generated by the lamp driving circuit **505** is input, the switch circuit is cut off and so the capacitive voltage divider is performed; and when the low frequency AC signal of the commercial power or the direct current of battery is input, the switch circuit bypasses the capacitor(s).

It is worth noting that the switch circuit may have plural switch units to have two or more switch terminals connecting in parallel with plural parallel-connected capacitors (e.g., the capacitors **645** and **646** in FIG. **51**A, the capacitors **643**, **645** and **646** in FIG. **51**A, the capacitors **743** and **744** or/and the capacitors **745** and **746** in FIG. **51**B, the capacitors **843** and **844** in FIG. **51**C, the capacitors **845** and **846** in FIG. **51**C, the capacitors **842**, **843** and **844** in FIG. **51**C, the capacitors **842**, **845** and **846** in FIG. **51**C, and the capacitors **842**, **843**, **844**, **845** and **846** in FIG. **51**C) to achieve the effect of bypassing the plural capacitors equivalently serial-connected with the LED tube lamp.

In addition, the ballast detection circuit of the present invention can be used in conjunction with the mode switching circuits shown in FIGS. **57**A-**57**I. The switch circuit of the ballast detection circuit is replaced with the mode switching circuit. The detection circuit of the ballast detection circuit is coupled to one of the pins **501**, **502**, **503** and **504** for detecting the signal input into the LED lamp through the pins **501**, **502**, **503** and **504**. The detection circuit generates a control signal to control the mode switching circuit being at the first mode or the second mode according to whether the signal is a high frequency, low frequency or DC signal, i.e., the frequency of the signal.

For example, when the signal is a high frequency signal and higher than a defined mode switch frequency, such as the signal provided by the lamp driving circuit **505**, the control signal generated by the detection circuit makes the mode switching circuit be at the second mode for directly inputting the filtered signal into the LED module. When the signal is a low frequency signal or a direct signal and lower than the defined mode switch frequency, such as the signal provided by the commercial power or the battery, the control signal generated by the detection circuit makes the mode switching circuit be at the first mode for directly inputting the filtered signal into the driving circuit.

FIG. **63**A is a block diagram of a power supply module in an LED tube lamp according to an embodiment of the present invention. Compared to that shown in FIG. **60**A, the present embodiment comprises two rectifying circuits **510** and **540**, a filtering circuit **520**, an LED lighting module **530**, two filament-simulating circuits **1560**, and further comprises an auxiliary power module **2510**. The auxiliary power module **2510** is coupled between the filtering output terminals **521** and **522**. The auxiliary power module **2510** detects the filtered signal in the filtering output terminals **521** and **522**, and determines whether providing an auxiliary power to the filtering output terminals **521** and **522** based on the detected result. When the supply of the filtered signal is stopped or a logic level thereof is insufficient, i.e., when a drive voltage for the LED module is below a defined voltage, the auxiliary power module provides auxiliary power to keep the LED lighting module **530** continuing to emit light. The defined voltage is determined according to an auxiliary power voltage of the auxiliary power module **2510**.

The filament-simulating circuits **1560** may be omitted and are therefore depicted by dotted lines.

FIG. **63**B is a block diagram of a power supply module in an LED tube lamp according to an embodiment of the present invention. Compared to that shown in FIG. **63**A, the present embodiment comprises two rectifying circuits **510** and **540**, a filtering circuit **520**, an LED lighting module **530**, two filament-simulating circuits **1560**, and an auxiliary power module **2510**, and the LED lighting module **530** further comprises a driving circuit **1530** and an LED module **630**. The auxiliary power module **2510** is coupled between the driving output terminals **1521** and **1522**. The auxiliary power module **2510** detects the driving signal in the driving output terminals **1521** and **1522**, and determines whether to provide an auxiliary power to the driving output terminals **1521** and **1522** based on the detected result. When the driving signal is no longer being supplied or a logic level thereof is insufficient, the auxiliary power module **2510** provides the auxiliary power to keep the LED module **630** continuously light. The filament-simulating circuits **1560** may be omitted and are therefore depicted by dotted lines.

FIG. **63**C is a schematic diagram of an auxiliary power module according to an embodiment of the present invention. The auxiliary power module **2610** comprises an energy storage unit **2613** and a voltage detection circuit **2614**. The auxiliary power module further comprises an auxiliary power positive terminal **2611** and an auxiliary power negative terminal **2612** for being respectively coupled to the filtering output terminals **521** and **522** or the driving output terminals **1521** and **1522**. The voltage detection circuit **2614** detects a logic level of a signal at the auxiliary power positive terminal **2611** and the auxiliary power negative terminal **2612** to determine whether releasing outward the power of the energy storage unit **2613** through the auxiliary power positive terminal **2611** and the auxiliary power negative terminal **2612**.

In the present embodiment, the energy storage unit **2613** is a battery or a supercapacitor. When a voltage difference of the auxiliary power positive terminal **2611** and the auxiliary power negative terminal **2612**(the drive voltage for the LED module) is higher than the auxiliary power voltage of the energy storage unit **2613**, the voltage detection circuit **2614** charges the energy storage unit **2613** by the signal in the auxiliary power positive terminal **2611** and the auxiliary power negative terminal **2612**. When the drive voltage is lower than the auxiliary power voltage, the energy storage unit **2613** releases the stored energy outward through the auxiliary power positive terminal **2611** and the auxiliary power negative terminal **2612**.

The voltage detection circuit **2614** comprises a diode **2615**, a bipolar junction transistor (BJT) **2616** and a resistor **2617**. A positive end of the diode **2615** is coupled to a positive end of the energy storage unit **2613** and a negative end of the diode **2615** is coupled to the auxiliary power positive terminal **2611**. The negative end of the energy storage unit **2613** is coupled to the auxiliary power negative terminal **2612**. A collector of the BJT **2616** is coupled to the auxiliary power positive terminal **2611**, and an emitter thereof is coupled to the positive end of the energy storage unit **2613**. One end of the resistor **2617** is coupled to the auxiliary power positive terminal **2611** and the other end is coupled to a base of the BJT **2616**. When the collector of the BJT **2616** is a cut-in voltage higher than the emitter thereof, the resistor **2617** conducts the BJT **2616**. When the power source provides power to the LED tube lamp normally, the energy storage unit **2613** is charged by the filtered signal through the filtering output terminals **521** and **522** and the conducted BJT **2616** or by the driving signal through the driving output terminals **1521** and **1522** and the conducted BJT **2616** until that the collector-emitter voltage of the BJT **2616** is lower than or equal to the cut-in voltage. When the filtered signal or the driving signal is no longer being supplied or the logic level thereof is insufficient, the energy storage unit **2613** provides power through the diode **2615** to keep the LED lighting module **530** or the LED module **630** continuously light.

It is worth noting that in some embodiments, the maximum voltage of the charged energy storage unit **2613** is at least one cut-in voltage of the BJT **2616** lower than the voltage difference applied between the auxiliary power positive terminal **2611** and the auxiliary power negative terminal **2612**. The voltage difference provided between the auxiliary power positive terminal **2611** and the auxiliary power negative terminal **2612** is a turn-on voltage of the diode **2615** lower than the voltage of the energy storage unit **2613**. Hence, when the auxiliary power module **2610** provides power, the voltage applied at the LED module **630** is lower (about the sum of the cut-in voltage of the BJT **2616** and the turn-on voltage of the diode **2615**). In the embodiment shown in the FIG. **63**B, the brightness of the LED module **630** is reduced when the auxiliary power module supplies power thereto. Thereby, when the auxiliary power module is applied to an emergency lighting system or a constant lighting system, the user realizes the main power supply, such as commercial power, is abnormal and then performs necessary precautions therefor.

Referring to FIG. **64**A, a block diagram of an LED tube lamp including a power supply module in accordance with certain embodiments is illustrated. Compared to the LED lamp shown in FIG. **49**B, the LED tube lamp of FIG. **64**A comprises two rectifying circuits **510** and **540**, a filtering circuit **520**, and an LED lighting module **530**, and further comprises an installation detection module **2520**. The installation detection module **2520** is coupled to the rectifying circuit **510** (and/or the rectifying circuit **540**) via an installation detection terminal **2521** and is coupled to the filtering circuit **520** via an installation detection terminal **2522**. The installation detection module **2520** detects the signal passing through the installation detection terminals **2521** and **2522** and determines whether to cut off an LED driving signal (e.g., an external driving signal) passing through the LED tube lamp based on the detected result. The installation detection module includes circuitry configured to perform these steps, and thus may be referred to as an installation detection circuit, or more generally as a detection circuit or cut-off circuit. When an LED tube lamp is not yet installed on a lamp socket or holder, or in some cases if it is not installed properly or is only partly installed (e.g., one side is connected to a lamp socket, but not the other side yet), the installation detection module **2520** detects a smaller current and determines the signal is passing through a high impedance. In this case, in certain embodiments, the installation detection circuit **2520** is in a cut-off state to make the LED tube lamp stop working. Otherwise, the installation detection module **2520** determines that the LED tube lamp has already been installed on the lamp socket or holder, and it keeps on conducting to make the LED tube lamp working normally.

For example, in some embodiments, when a current passing through the installation detection terminals is greater than or equal to a specific, defined installation current (or a current value), which may indicate that the current supplied to the lighting module **530** is greater than or equal to a specific, defined operating current, the installation detection module is conductive to make the LED tube lamp operate in a conductive state. For example, a current greater than or equal to the specific current value may indicate that the LED tube lamp has correctly been installed in the lamp socket or holder. When the current passing through the installation detection terminals is smaller than the specific, defined installation current (or the current value), which may indicate that the current supplied to the lighting module **530** is less than a specific, defined operating current, the installation detection module cuts off current to make the LED tube lamp enter in a non-conducting state based on determining that the LED tube lamp has been not installed in, or does not properly connect to, the lamp socket or holder. In certain embodiments, the installation detection module **2520** determines conducting or cutting off based on the impedance detection to make the LED tube lamp operate in a conducting state or enter non-conducting state. The LED tube lamp operating in a conducting state may refer to the LED tube lamp including a sufficient current passing through the LED module to cause the LED light sources to emit light. The LED tube lamp operating in a cut-off state may refer to the LED tube lamp including an insufficient current or no current passing through the LED module so that the LED light sources do not emit light. Accordingly, the occurrence of electric shock caused by touching the conductive part of the LED tube lamp which is incorrectly installed on the lamp socket or holder can be better avoided.

Referring to FIG. **64**B, a block diagram of an installation detection module in accordance with certain embodiments is illustrated. The installation detection module includes a switch circuit **2580**, a detection pulse generating module **2540**, a detection result latching circuit **2560**, and a detection determining circuit **2570**. Certain of these circuits or modules may be referred to as first, second, third, etc., circuits as a naming convention to differentiate them from each other.

The detection determining circuit **2570** is coupled to and detects the signal between the installation detection terminals **2521** (through a switch circuit coupling terminal **2581** and the switch circuit **2580**) and **2522**. It is also coupled to the detection result latching circuit **2560** via a detection result terminal **2571** to transmit the detection result signal. The detection determining circuit **2570** may be configured to detect a current passing through terminals **2521** and **2522** (e.g., to detect whether the current is above or below a specific value).

The detection pulse generating module **2540** is coupled to the detection result latching circuit **2560** via a pulse signal output terminal **2541**, and generates a pulse signal to inform the detection result latching circuit **2560** of a time point for latching (storing) the detection result. For example, the detection pulse generating module **2540** may be a circuit configured to generate a signal that causes a latching circuit, such as the detection result latching circuit **2560** to enter and remain in a state that corresponds to one of a conducting state or a cut-off state for the LED tube lamp. The detection result latching circuit **2560** stores the detection result according to the detection result signal (or detection result signal and pulse signal), and transmits or provides the detection result to the switch circuit **2580** coupled to the detection result latching circuit **2560** via a detection result latching terminal **2561**. The switch circuit **2580** controls the state between conducting or cut off between the installation detection terminals **2521** and **2522** according to the detection result.

Referring to FIG. **64**C, a block diagram of a detection pulse generating module in accordance with certain embodiments is illustrated. A detection pulse generating module **2640** may be a circuit that includes multiple capacitors **2642**, **2645**, and **2646**, multiple resistors **2643**, **2647**, and **2648**, two buffers **2644**, and **2651**, an inverter **2650**, a diode **2649**, and an OR gate **2652**. With use or operation, the capacitor **2642** and the resistor **2643** connect in series between a driving voltage (e.g., a driving voltage source, which may be a node of a power supply), such as VCC usually defined as a high logic level voltage, and a reference voltage (or potential), such as ground potential in this embodiment. The connection node between the capacitor **2642** and the resistor **2643** is coupled to an input terminal of the buffer **2644**. The resistor **2647** is coupled between the driving voltage, e.g., VCC, and an input terminal of the inverter **2650**. The resistor **2648** is coupled between an input terminal of the buffer **2651** and the reference voltage, e.g. ground potential in this embodiment. An anode of the diode **2649** is grounded and a cathode thereof is coupled to the input terminal of the buffer **2651**. First ends of the capacitors **2645** and **2646** are jointly coupled to an output terminal of the buffer **2644**, and second, opposite ends of the capacitors **2645** and **2646** are respectively coupled to the input terminal of the inverter **2650** and the input terminal of the buffer **2651**. An output terminal of the inverter **2650** and an output terminal of the buffer **2651** are coupled to two input terminals of the OR gate **2652**. According to certain embodiments, the voltage (or potential) for "high logic level" and "low logic level" mentioned in this specification are all relative to another voltage (or potential) or a certain reference voltage (or potential) in circuits, and further may be described as "logic high logic level" and "logic low logic level."

When an end cap of an LED tube lamp is inserted into a lamp socket and the other end cap thereof is electrically coupled to a human body, or when both end caps of the LED tube lamp are inserted into the lamp socket, the LED tube lamp is conductive with electricity. At this moment, the installation detection module enters a detection stage. The voltage on the connection node of the capacitor **2642** and the resistor **2643** is high initially (equals to the driving voltage, VCC) and decreases with time to zero finally. The input terminal of the buffer **2644** is coupled to the connection node of the capacitor **2642** and the resistor **2643**, so the buffer **2644** outputs a high logic level signal at the beginning and changes to output a low logic level signal when the voltage on the connection node of the capacitor **2642** and the resistor **2643** decreases to a low logic trigger logic level. As a result, the buffer **2644** is configured to produce an input pulse signal and then remain in a low logic level thereafter (stops outputting the input pulse signal.) The width for the input pulse signal may be described as equal to one (initial setting) time period, which is determined by the capacitance value of the capacitor **2642** and the resistance value of the resistor **2643**.

Next, the operations for the buffer **2644** to produce the pulse signal with the initial setting time period will be described below. Since the voltage on a first end of the capacitor **2645** and on a first end of the resistor **2647** is equal to the driving voltage VCC, the voltage on the connection node of both of them is also a high logic level. The first end of the resistor **2648** is grounded and the first end of the capacitor **2646** receives the pulse signal from the buffer **2644**, so the connection node of the capacitor **2646** and the resistor **2648** has a high logic level voltage at the beginning but this voltage decreases with time to zero (in the meantime, the capacitor stores the voltage being equal to or approaching the driving voltage VCC.) Accordingly, initially the inverter **2650** outputs a low logic level signal and the buffer **2651** outputs a high logic level signal, and hence the OR gate **2652** outputs a high logic level signal (a first pulse signal) at the pulse signal output terminal **2541**. At this moment, the detection result latching circuit **2560** stores the detection result for the first time according to the detection result signal and the pulse signal. During that initial pulse time period, detection pulse generating module **2540** outputs a high logic level signal, which results in the detection result latching circuit **2560** outputting the result of that high logic level signal.

When the voltage on the connection node of the capacitor **2646** and the resistor **2648** decreases to the low logic trigger logic level, the buffer **2651** changes to output a low logic level signal to make the OR gate **2652** output a low logic level signal at the pulse signal output terminal **2541** (stops outputting the first pulse signal.) The width of the first pulse signal output from the OR gate **2652** is determined by the capacitance value of the capacitor **2646** and the resistance value of the resistor **2648**.

The operation after the buffer **2644** stops outputting the pulse signal is described as below. For example, the operation may be initially in an operating stage. Since the capacitor **2646** stores the voltage being almost equal to the driving voltage VCC, and when the buffer **2644** instantaneously changes its output from a high logic level signal to a low logic level signal, the voltage on the connection node of the capacitor **2646** and the resistor **2648** is below zero but will be pulled up to zero by the diode **2649** rapidly charging the capacitor. Therefore, the buffer **2651** still outputs a low logic level signal.

On the other hand, when the buffer **2644** instantaneously changes its output from a high logic level signal to a low logic level signal, the voltage on the one end of the capacitor **2645** also changes from the driving voltage VCC to zero instantly. This makes the connection node of the capacitor **2645** and the resistor **2647** have a low logic level signal. At this moment, the output of the inverter **2650** changes to a high logic level signal to make the OR gate output a high logic level signal (a second pulse signal.) The detection result latching circuit **2560** stores the detection result for a second time according to the detection result signal and the pulse signal. Next, the driving voltage VCC charges the capacitor **2645** through the resistor **2647** to make the voltage on the connection node of the capacitor **2645** and the resistor **2647** increase with time to the driving voltage VCC. When the voltage on the connection node of the capacitor **2645** and the resistor **2647** increases to reach a high logic trigger logic level, the inverter **2650** outputs a low logic level signal again to make the OR gate **2652** stop outputting the second pulse signal. The width of the second pulse signal is determined by the capacitance value of the capacitor **2645** and the resistance value of the resistor **2647**.

As those mentioned above, in certain embodiments, the detection pulse generating module **2640** generates two high logic level pulse signals in the detection stage, which are the first pulse signal and the second pulse signal. These pulse signals are output from the pulse signal output terminal **2541**. Moreover, there is an interval with a defined time between the first and second pulse signals (e.g., an opposite-logic signal, which may have a low logic level when the pulse signals have a high logic level), and the defined time is determined by the capacitance value of the capacitor **2642** and the resistance value of the resistor **2643**).

From the detection stage entering the operating stage, the detection pulse generating module **2640** does not produce the pulse signal any more, and keeps the pulse signal output terminal **2541** on a low logic level potential. As described herein, the operating stage is the stage following the detection stage (e.g., following the time after the second pulse signal ends). The operating stage occurs when the LED tube lamp is at least partly connected to a power source, such as provided in a lamp socket. For example, the operating stage may occur when part of the LED tube lamp, such as only one side of the LED tube lamp, is properly connected to one side of a lamp socket, and part of the LED tube lamp is either connected to a high impedance, such as a person, and/or is improperly connected to the other side of the lamp socket (e.g., is misaligned so that the metal contacts in the socket do not contact metal contacts in the LED tube lamp). The operating stage may also occur when the entire LED tube lamp is properly connected to the lamp socket.

Referring to FIG. **64**D, a detection determining circuit in accordance with certain embodiments is illustrated. An exemplary detection determining circuit **2670** includes a comparator **2671**, and a resistor **2672**. A negative input terminal of the comparator **2671** receives a reference logic level signal (or a reference voltage) Vref, a positive input terminal thereof is grounded through the resistor **2672** and is also coupled to a switch circuit coupling terminal **2581**. Referring to FIGS. **64**B and **64**D, the signal flowing into the switch circuit **2580** from the installation detection terminal **2521** outputs to the switch circuit coupling terminal **2581** to the resistor **2672**. When the current of the signal passing through the resistor **2672** reaches a certain level (for example, bigger than or equal to a defined current for installation, (e.g. **2**A) and this makes the voltage on the resistor **2672** higher than the reference voltage Vref (referring to two end caps inserted into the lamp socket,) the comparator **2671** produces a high logic level detection result signal and outputs it to the detection result terminal **2571**. For example, when an LED tube lamp is correctly installed on a lamp socket, the comparator **2671** outputs a high logic level detection result signal at the detection result terminal **2571**, whereas the comparator **2671** generates a low logic level detection result signal and outputs it to the detection result terminal **2571** when a current passing through the resistor **2672** is insufficient to make the voltage on the resistor **2672** higher than the reference voltage Vref (referring to only one end cap inserted into the lamp socket.) Therefore, in some embodiments, when the LED tube lamp is incorrectly installed on the lamp socket or one end cap thereof is inserted into the lamp socket but the other one is grounded by an object such as a human body, the current will be too small to make the comparator **2671** output a high logic level detection result signal to the detection result terminal **2571**.

Referring to FIG. **64**E, a schematic detection result latching circuit according to some embodiments of the present invention is illustrated. A detection result latching circuit **2660** includes a D flip-flop **2661**, a resistor **2662**, and an OR gate **2663**. The D flip-flop **2661** has a CLK input terminal coupled to a detection result terminal **2571**, and a D input terminal coupled to a driving voltage VCC. When the detection result terminal **2571** first outputs a low logic level detection result signal, the D flip-flop **2661** initially outputs a low logic level signal at a Q output terminal thereof, but the D flip-flop **2661** outputs a high logic level signal at the Q output terminal thereof when the detection result terminal **2571** outputs a high logic level detection result signal. The resistor **2662** is coupled between the Q output terminal of the D flip-flop **2661** and a reference voltage, such as ground potential. When the OR gate **2663** receives the first or second pulse signals from the pulse signal output terminal **2541** or receives a high logic level signal from the Q output terminal of the D flip-flop **2661**, the OR gate **2663** outputs a high logic level detection result latching signal at a detection result latching terminal **2561**. The detection pulse generating module **2640** only in the detection stage outputs the first and the second pulse signals to make the OR gate **2663** output the high logic level detection result latching signal, and thus the D flip-flop **2661** decides the detection result latching signal to be the high logic level or the low logic level the rest of the time, e.g. including the operating stage after the detection stage. Accordingly, when the detection result terminal **2571** has no high logic level detection result signal, the D flip-flop **2661** keeps a low logic level signal at the Q output terminal to make the detection result latching terminal **2561** also keep a low logic level detection result latching signal in the detection stage. On the contrary, once the detection result terminal **2571** has a high logic level detection result signal, the D flip-flop **2661** outputs and keeps a high logic level signal (e.g., based on VCC) at the Q output terminal. In this way, the detection result latching terminal **2561** keeps a high logic level detection result latching signal in the operating stage as well.

Referring to FIG. **64**F, a schematic switch circuit according to some embodiments is illustrated. A switch circuit **2680** includes a transistor, such as a bipolar junction transistor (BJT) **2681**, as being a power transistor, which has the ability of dealing with high current/power and is suitable for the switch circuit. The BJT **2681** has a collector coupled to an installation detection terminal **2521**, a base coupled to a detection result latching terminal **2561**, and an emitter coupled to a switch circuit coupling terminal **2581**. When the detection pulse generating module **2640** produces the first and second pulse signals, the BJT **2681** is in a transient conduction state. This allows the detection determining circuit **2670** to perform the detection for determining the detection result latching signal to be a high logic level or a low logic level. When the detection result latching circuit **2660** outputs a high logic level detection result latching signal at the detection result latching terminal **2561**, the BJT **2681** is in the conducting state to make the installation detection terminals **2521** and **2522** conducting. In contrast, when the detection result latching circuit **2660** outputs a low logic level detection result latching signal at the detection result latching terminal **2561** and the output from detection pulse generating module **2640** is a low logic level, the BJT **2681** is cut-off or in the blocking state to make the installation detection terminals **2521** and **2522** cut-off or blocking.

Since the external driving signal is an AC signal and in order to avoid the detection error resulting from the logic level of the external driving signal being just around zero when the detection determining circuit **2670** detects, the detection pulse generating module **2640** generates the first and second pulse signals to let the detection determining circuit **2670** perform two detections. So the issue of the logic level of the external driving signal being just around zero in a single detection can be avoided. In some cases, the time difference between the productions of the first and second pulse signals is not multiple times of half one cycle of the external driving signal. For example, it does not correspond to the multiple phase differences of 180 degrees of the external driving signal. In this way, when one of the first and second pulse signals is generated and unfortunately the external driving signal is around zero, it can be avoided that the external driving signal is again around zero when the other pulse signal is generated.

The time difference between the productions of the first and second pulse signals, for example, an interval with a defined time between both of them can be represented as following:

the interval=$(X+Y)(T/2)$,

where T represents the cycle of an external driving signal, X is a natural number, $0<Y<1$, with Y in some embodiments in the range of 0.05-0.95, and in some embodiments in the range of 0.15-0.85.

Furthermore, in order to avoid the installation detection module entering the detection stage from misjudgment resulting from the logic level of the driving voltage VCC being too small, the first pulse signal can be set to be produced when the driving voltage VCC reaches or is higher than a defined logic level. For example, in some embodiments, the detection determining circuit **2670** works after the driving voltage VCC reaching a high enough logic level in order to prevent the installation detection module from misjudgment due to an insufficient logic level.

According to the examples mentioned above, when one end cap of an LED tube lamp is inserted into a lamp socket and the other one floats or electrically couples to a human body or other grounded object, the detection determining circuit outputs a low logic level detection result signal because of high impedance. The detection result latching circuit stores the low logic level detection result signal based on the pulse signal of the detection pulse generating module, making it as the low logic level detection result latching signal, and keeps the detection result in the operating stage, without changing the logic value. In this way, the switch circuit keeps cutting-off or blocking instead of conducting continually. And further, the electric shock situation can be prevented and the requirement of safety standard can also be met. On the other hand, when two end caps of the LED tube lamp are correctly inserted into the lamp socket, the detection determining circuit outputs a high logic level detection result signal because the impedance of the circuit for the LED tube lamp itself is small. The detection result latching circuit stores the high logic level detection result signal based on the pulse signal of the detection pulse generating module, making it as the high logic level detection result latching signal, and keeps the detection result in the operating stage. So the switch circuit keeps conducting to make the LED tube lamp work normally in the operating stage.

In some embodiments, when one end cap of the LED tube lamp is inserted into the lamp socket and the other one floats or electrically couples to a human body, the detection determining circuit outputs a low logic level detection result signal to the detection result latching circuit, and then the detection pulse generating module outputs a low logic level signal to the detection result latching circuit to make the detection result latching circuit output a low logic level detection result latching signal to make the switch circuit cutting-off or blocking. As such, the switch circuit blocking makes the installation detection terminals, e.g. the first and second installation detection terminals, blocking. As a result, the LED tube lamp is in non-conducting or blocking state.

However, in some embodiments, when two end caps of the LED tube lamp are correctly inserted into the lamp socket, the detection determining circuit outputs a high logic level detection result signal to the detection result latching circuit to make the detection result latching circuit output a high logic level detection result latching signal to make the switch circuit conducting. As such, the switch circuit conducting makes the installation detection terminals, e.g. the first and second installation detection terminals, conducting. As a result, the LED tube lamp operates in a conducting state.

Thus, according to the operation of the installation detection module, a first circuit, upon connection of at least one end of the LED tube lamp to a lamp socket, generates and outputs two pulses, each having a pulse width, with a time period between the pulses. The first circuit may include various of the elements described above configured to output the pulses to a base of a transistor (e.g., a BJT transistor) that serves as a switch. The pulses occur during a detection stage for detecting whether the LED tube lamp is properly connected to a lamp socket. The timing of the pulses may be controlled based on the timing of various parts of the first circuit changing from high to low logic levels, or vice versa.

The pulses can be timed such that, during that detection stage time, if the LED tube lamp is properly connected to the lamp socket (e.g., both ends of the LED tube lamp are correctly connected to conductive terminals of the lamp socket), at least one of the pulse signals occurs when an AC current from a driving signal is at a non-zero level. For example, the pulse signals can occur at intervals that are different from half of the period of the AC signal. For example, respective start points or mid points of the pulse signals, or a time between an end of the first pulse signal and a beginning of the second pulse signal may be separated by an amount of time that is different from half of the period of the AC signal (e.g., it may be between 0.05 and 0.95 percent of a multiple of half of the period of the AC signal). During a pulse that occurs when the AC signal is at a non-zero level, a switch that receives the AC signal at the non-zero level may be turned on, causing a latch circuit to change states such that the switch remains permanently on so long as the LED tube lamp remains properly connected to the lamp socket. For example, the switch may be configured to turn on when each pulse is output from the first circuit. The latch circuit may be configured to change state only when the switch is on and the current output from the switch is above a threshold value, which may indicate a proper connection to a light socket. As a result, the LED tube lamp operates in a conducting state.

On the other hand, if both pulses occur when a driving signal at the LED tube lamp has a near-zero current level, or a current level below a particular threshold, then the state of the latch circuit is not changed, and so the switch is only on during the two pulses, but then remains permanently off after the pulses and after the detection mode is over. For example, the latch circuit can be configured to remain in its present state if the current output from the switch is below the threshold value. In this manner, the LED tube lamp remains in a non-conducting state, which prevents electric shock, even though part of the LED tube lamp is connected to an electrical power source..

It is worth noting that according to certain embodiments, the width of the pulse signal generated by the detection pulse generating module is between **10** us to **1** ms, and it is used to make the switch circuit conducting for a short period when the LED tube lamp conducts instantaneously. In some embodiments, a pulse current is generated to pass through the detection determining circuit for detecting and determining. Since the pulse is for a short time and not for a long time, the electric shock situation will not occur. Furthermore, the detection result latching circuit also keeps the detection result during the operating stage (e.g., the operating stage being the period after the detection stage and during which part of the LED tube lamp is still connected to a power source), and no longer changes the detection result stored previously complying with the circuit state changing. A situation resulting from changing the detection result can thus be avoided. In some embodiments, the installation detection module, such as the switch circuit, the detection pulse generating module, the detection result latching circuit, and the detection determining circuit, could be integrated into a chip and then embedded in circuits for saving the circuit cost and layout space.

As discussed in the above examples, in some embodiments, an LED tube lamp includes an installation detection circuit comprising a first circuit configured to output two pulse signals, the first pulse signal output at a first time and the second pulse signal output at a second time after the first time, and a switch configured to receive an LED driving signal and to receive the two pulse signals, wherein the two pulse signals control turning on and off of the switch. The installation detection circuit may be configured to, during a detection stage, detect during each of the two pulse signals whether the LED tube lamp is properly connected to a lamp socket. When it is not detected during either pulse signal that the LED tube lamp is properly connected to the lamp socket, the switch may remain in an off state after the detection stage. When it is detected during at least one of the pulse signals that the LED tube lamp is properly connected to the lamp socket, the switch may remain in an on state after the detection stage. The two pulse signals may occur such that they are separated by a time different from a multiple of half of a period of the LED driving signal, and such that at least one of them does not occur when the LED driving signal has a current value of substantially zero. It should be noted that although a circuit for producing two pulse signals is described, the disclosure is not intended to be limiting as such. For example, a circuit may be implemented such that a plurality of pulse signals may occur, wherein at least two of the plurality of pulse signals are separated by a time different from a multiple of half of a period of the LED driving signal, and such that at least one of the plurality of pulse signals does not occur when the LED driving signal has a current value of substantially zero.

For example, according to the design of the power supply in some embodiments, the circuit board assembly has a long circuit sheet and a short circuit board that are adhered to each other with the short circuit board being adjacent to the side edge of the long circuit sheet. The short circuit board may be provided with power supply module to form the power supply, and may include the installation detection module.

According to the design of the power supply module, the external driving signal may be a low frequency AC signal (e.g., commercial power), a high frequency AC signal (e.g., that provided by an electronic ballast), or a DC signal (e.g., that provided by a battery or external configured driving source), input into the LED tube lamp through a drive architecture of dual-end power supply. For the drive architecture of dual-end power supply, the external driving signal may be input by using only one end thereof as single-end power supply.

The LED tube lamp may omit the rectifying circuit in the power supply module when the external driving signal is a DC signal.

According to the design of the rectifying circuit in the power supply module, there may be a dual rectifying circuit. First and second rectifying circuits of the dual rectifying circuit are respectively coupled to the two end caps disposed on two ends of the LED tube lamp. The dual rectifying circuit is applicable to the drive architecture of dual-end power supply. Furthermore, the LED tube lamp having at least one rectifying circuit is applicable to the drive architecture of a low frequency AC signal, high frequency AC signal or DC signal.

The dual rectifying circuit may comprise, for example, two half-wave rectifier circuits, two full-wave bridge rectifying circuits or one half-wave rectifier circuit and one full-wave bridge rectifying circuit.

According to the design of the pin in the LED tube lamp, there may be two pins in single end (the other end has no pin), two pins in corresponding ends of two ends, or four pins in corresponding ends of two ends. The designs of two pins in single end and two pins in corresponding ends of two ends are applicable to a signal rectifying circuit design of the rectifying circuit. The design of four pins in corresponding ends of two ends is applicable to a dual rectifying circuit design of the rectifying circuit, and the external driving signal can be received by two pins in only one end or any pin in each of two ends.

According to the design of the filtering circuit of the power supply module, there may be a single capacitor, ori filter circuit. The filtering circuit filters the high frequency component of the rectified signal for providing a DC signal with a low ripple voltage as the filtered signal. The filtering circuit also further comprises the LC filtering circuit having a high impedance for a specific frequency for conforming to current limitations in specific frequencies of the UL standard. Moreover, the filtering circuit according to some embodiments further comprises a filtering unit coupled between a rectifying circuit and the pin(s) for reducing the EMI resulted from the circuit(s) of the LED tube lamp. The LED tube lamp may omit the filtering circuit in the power supply module when the external driving signal is a DC signal.

According to the design of the LED lighting module in some embodiments, the LED lighting module may comprise the LED module and the driving circuit or only the LED module. The LED module may be connected with a voltage stabilization circuit in parallel for preventing the LED module from over voltage. The voltage stabilization circuit may be a voltage clamping circuit, such as zener diode, DIAC and so on. When the rectifying circuit has a capacitive circuit, in some embodiments, two capacitors are respectively coupled between two corresponding pins in two end caps and so the two capacitors and the capacitive circuit as a voltage stabilization circuit perform a capacitive voltage divider.

If there are only the LED module in the LED lighting module and the external driving signal is a high frequency AC signal, a capacitive circuit (e.g., having at least one capacitor) is in at least one rectifying circuit and the capacitive circuit is connected in series with a half-wave rectifier circuit or a full-wave bridge rectifying circuit of the rectifying circuit and serves as a current modulation circuit (or a current regulator) to modulate or to regulate the current of the LED module due to that the capacitor equates a resistor for a high frequency signal. Thereby, even different ballasts provide high frequency signals with different voltage logic levels, the current of the LED module can be modulated into a defined current range for preventing overcurrent. In addition, an energy-releasing circuit is connected in parallel with the LED module. When the external driving signal is no longer supplied, the energy-releasing circuit releases the energy stored in the filtering circuit to lower a resonance effect of the filtering circuit and other circuits for restraining the flicker of the LED module. In some embodiments, if there are the LED module and the driving circuit in the LED lighting module, the driving circuit may be a buck converter, a boost converter, or a buck-boost converter. The driving circuit stabilizes the current of the LED module at a defined current value, and the defined current value may be modulated based on the external driving signal. For example, the defined current value may be increased with the increasing of the logic level of the external driving signal and reduced with the reducing of the logic level of the external driving signal. Moreover, a mode switching circuit may be added between the LED module and the driving circuit for switching the current from the filtering circuit directly or through the driving circuit inputting into the LED module.

A protection circuit may be additionally added to protect the LED module. The protection circuit detects the current and/or the voltage of the LED module to determine whether to enable corresponding over current and/or over voltage protection.

According to the design of the ballast detection circuit of the power supply module, the ballast detection circuit is substantially connected in parallel with a capacitor connected in series with the LED module and determines the external driving signal whether flowing through the capacitor or the ballast detection circuit (i.e., bypassing the capacitor) based on the frequency of the external driving signal. The capacitor may be a capacitive circuit in the rectifying circuit.

According to the design of the filament-simulating circuit of the power supply module, there may be a single set of a parallel-connected capacitor and resistor, two serially connected sets, each having a parallel-connected capacitor and resistor, or a negative temperature coefficient circuit. The filament-simulating circuit is applicable to program-start ballast for avoiding the program-start ballast determining the filament abnormally, and so the compatibility of the LED tube lamp with program-start ballast is enhanced. Furthermore, the filament-simulating circuit almost does not affect the compatibilities for other ballasts, e.g., instant-start and rapid-start ballasts.

According to the design of the ballast-compatible circuit of the power supply module in some embodiments, the ballast-compatible circuit can be connected in series with the rectifying circuit or connected in parallel with the filtering circuit and the LED lighting module. Under the design of being connected in series with the rectifying circuit, the ballast-compatible circuit is initially in a cutoff state and then changes to a conducting state in an objective delay. Under the design of being connected in parallel with the filtering circuit and the LED lighting module, the ballast-compatible circuit is initially in a conducting state and then changes to a cutoff state in an objective delay. The ballast-compatible circuit makes the electronic ballast really activate during the starting stage and enhances the compatibility for instant-start ballast. Furthermore, the ballast-compatible circuit almost does not affect the compatibilities with other ballasts, e.g., program-start and rapid-start ballasts.

According to the design of the auxiliary power module of the power supply module, the energy storage unit may be a battery or a supercapacitor, connected in parallel with the LED module. The auxiliary power module is applicable to the LED lighting module having the driving circuit.

According to the design of the LED module of the power supply module, the LED module comprises plural strings of LEDs connected in parallel with each other, wherein each LED may have a single LED chip or plural LED chips emitting different spectrums. Each LEDs in different LED strings may be connected with each other to form a mesh connection.

In other words, the abovementioned features can be implemented in any combination to improve the LED tube lamp.

While the instant disclosure has been described by way of example and in terms of the preferred embodiments, it is to be understood that the instant disclosure needs not be limited to the disclosed embodiments. For anyone skilled in the art, various modifications and improvements within the spirit of the instant disclosure are covered under the scope of the instant disclosure. The covered scope of the instant disclosure is based on the appended claims.

What is claimed is:

1. An LED tube lamp, comprising:

a lamp tube;

two end caps, each of the two end caps coupled to a respective end of the lamp tube;

a power supply disposed in one or two end caps;

an LED light strip disposed on an inner circumferential surface of the lamp tube, the LED light strip comprising a mounting region and a connecting region, the mounting region for mounting a plurality of LED light sources, the connecting region having at least two soldering pads, and the mounting region and the connecting region being electrically connected to the plurality of LED light sources and the power supply; and

a protective layer disposed on a surface of the LED light strip, the protective layer having a plurality of first openings to accommodate the plurality of LED light sources and at least two second openings to accommodate the at least two soldering pads.

2. The LED tube lamp as claimed in claim **1**, wherein the protective layer further comprises a third opening adjacent to the two second openings.

3. The LED tube lamp as claimed in claim **2**, wherein the LED light strip further comprises a fourth opening arranged on the connecting region and corresponding to the third opening on the protective layer, further wherein the third opening and the fourth opening form a through hole.

4. The LED tube lamp as claimed in claim **3**, wherein the through hole is arranged between the two soldering pads.

5. The LED tube lamp as claimed in claim **3**, wherein the through hole allows a soldering machine to recognize the position of the soldering pads during a soldering process.

6. The LED tube lamp as claimed in claim **1**, wherein the LED light strip further comprises a first wiring layer, wherein the plurality of LED light sources are disposed on a first side of the first wiring layer and are electrically connected to the first wiring layer.

7. The LED tube lamp as claimed in claim **6**, wherein the LED light strip further comprises a second wiring layer disposed on a second side of the first wiring layer, wherein the second wiring layer is made of metal.

8. The LED tube lamp as claimed in claim **7**, wherein the LED light strip further comprises a dielectric layer disposed between the first wiring layer and the second wiring layer.

9. The LED tube lamp as claimed in claim **1**, wherein at least one of the two end caps comprises at least one conductive pin electrically connected to the power supply.

10. The LED tube lamp as claimed in claim **1**, further comprising a diffusion film coated on a surface of the lamp tube.

11. The LED tube lamp as claimed in claim **10**, wherein the diffusion film is coated on an inner surface of the lamp tube.

12. The LED tube lamp as claimed in claim **10**, wherein the diffusion film comprises a sheet and covers without contacting the LED light sources.

13. The LED tube lamp as claimed in claim **1**, wherein the LED light strip attached to an inner surface of the lamp tube.

14. The LED tube lamp as claimed in claim **1**, wherein the power supply comprises a circuit board disposed inside one of the end caps, the circuit board electrically connecting the connecting region.

15. The LED tube lamp as claimed in claim **14**, wherein the circuit board is parallel to a longitudinal direction of the lamp tube.

16. The LED tube lamp as claimed in claim **14**, wherein the circuit board is perpendicular to a longitudinal direction of the lamp tube.

17. The LED tube lamp as claimed in claim **1**, further comprising a first pin and a second pin coupled to one of the two end caps, and a third pin coupled to the other end cap; and wherein the power supply comprises:

a first rectifying circuit connected to the first and second pins;

a second rectifying circuit connected to the third pin and an output terminal of the first rectifying circuit, wherein the first and second rectifying circuits are configured for rectifying an external driving signal to produce a rectified signal; and

a driving circuit coupled to the first and second rectifying circuits, for driving the LED light sources,

wherein the LED tube lamp is configured to receive the external driving signal and emit light in each of two power supply arrangements, a first power supply arrangement being that the external driving signal is a low frequency signal input and transmitted through the first and second pins, and a second power supply arrangement being that the external driving signal is a low frequency signal input and transmitted through one of the first and second pins and through the third pin across the two ends of the lamp tube; and

the LED tube lamp is configured such that when the external driving signal is a low frequency signal, the LED tube lamp causes the rectified signal to be used by the driving circuit for driving the LED light sources to emit light.

18. The LED tube lamp as claimed in claim **17**, wherein the external driving signal is a low frequency signal having a frequency between 0 and 60 Hz.

19. The LED tube lamp as claimed in claim **17**, wherein the first rectifying circuit comprises a first diode, a second diode, a third diode and a fourth diode, the first pin is connected to a first common node connecting an anode of the first diode and a cathode of the second diode, and the second pin is connected to a second common node connecting an anode of the third diode and a cathode of the fourth diode.

20. The LED tube lamp as claimed in claim **19**, wherein the second rectifying circuit comprises a fifth diode and a sixth diode and has a third common node connecting an anode of the fifth diode and a cathode of the sixth diode of the second rectifying circuit, and the third common node is coupled to the third pin, and further wherein a common anode of the second and the fourth diodes of the first rectifying circuit is coupled to an anode of one of the fifth and sixth diodes of the second rectifying circuit, and a common cathode of the first and third diodes of the first rectifying circuit is coupled to a cathode of the other one of the fifth and sixth diodes of the second rectifying circuit.

21. The LED tube lamp as claimed in claim **17**, wherein the LED tube lamp is configured such that the driving circuit does not drive the LED light sources to emit light, when an external driving signal input through one of the first and second pins and the third pin across the two ends of the lamp tube is provided by an electrical ballast.

22. The LED tube lamp as claimed in claim **21**, wherein when the external driving signal provided by an electrical ballast is input across the two ends of the lamp tube, the rectified signal bypasses at least a component of the driving circuit, and the driving circuit drives the LED light sources to emit light.

23. The LED tube lamp as claimed in claim **1**, further comprising a first pin and a second pin coupled to one of the two end caps, and a third pin coupled to the other end cap; and wherein the power supply comprises:

a first rectifying circuit comprising diodes, the first rectifying circuit connected to the first and second pins;

a second rectifying circuit comprising diodes, the second rectifying circuit connected to the third pin and an output terminal of the first rectifying circuit, wherein the first and second rectifying circuits are configured to rectify an external driving signal to produce a rectified signal; and

a detection circuit coupled to the first and the second rectifying circuits and the LED light sources, and configured for determining whether to cause the LED light sources to be driven by the rectified signal, or to prevent the LED light sources from being driven by the rectified signal,

wherein the LED tube lamp is configured to receive the external driving signal and emit light in each of two power supply arrangements, a first power supply arrangement being that the external driving signal is input and transmitted through the first and second pins, and a second power supply arrangement being that the external driving signal is input and transmitted through one of the first and second pins and through the third pin across the two ends of the lamp tube.

24. The LED tube lamp as claimed in claim **23**, wherein the power supply further comprises a driving circuit coupled to the first and the second rectifying circuits and the LED light sources, and configured to drive the LED light sources.

25. The LED tube lamp as claimed in claim **24**, wherein when the external driving signal is a low frequency signal from an AC powerline, the driving circuit is configured to drive the LED light sources to emit light.

26. The LED tube lamp as claimed in claim **24**, wherein the detection circuit comprises a mode switching circuit coupled to the first and the second rectifying circuits and the driving circuit, and configured to cause the rectified signal to be used by the driving circuit when the external driving signal is a low frequency signal from an AC powerline.

27. The LED tube lamp as claimed in claim **23**, wherein the first rectifying circuit comprises four diodes, the first pin is connected to a first common node connecting an anode and a cathode respectively of two of the four diodes, and the second pin is connected to a second common node connecting an anode and a cathode respectively of the other two of the four diodes.

28. The LED tube lamp as claimed in claim **27**, wherein the second rectifying circuit comprises two diodes having a third common node connecting an anode and a cathode respectively of the two diodes of the second rectifying circuit, and the third common node is coupled to the third pin; and a common anode of two of the four diodes of the first rectifying circuit is coupled to an anode of one of the two diodes of the second rectifying circuit, and a common cathode of the other two of the four diodes of the first rectifying circuit is coupled to a cathode of the other one of the two diodes of the second rectifying circuit.

29. An LED tube lamp, comprising:

a lamp tube;

two end caps attached at two ends of the lamp tube respectively;

a power supply disposed in one or both of the end caps;

a light strip disposed inside the lamp tube, the light strip comprising a mounting region and a connecting region;

a plurality of LED light sources mounted on the mounting region, the mounting region and the connecting region being electrically connected to the plurality of LED light sources and the power supply;

at least two soldering pads arranged on the connecting region for electrically connecting the power supply;

a recognizing mark arranged on the connecting region; and

a protective layer disposed on the light strip.

30. The LED tube lamp as claimed in claim **29**, wherein the protective layer comprises a plurality of first openings arranged on the mounting region for accommodating the LED light sources and at least two second openings arranged on the connecting region for accommodating the at least two soldering pads.

31. The LED tube lamp as claimed in claim **30**, wherein the protective layer further comprises a third opening, wherein the third opening comprises the recognizing mark.

32. The LED tube lamp as claimed in claim **31**, wherein the LED light strip attached to an inner surface of the lamp tube.

33. The LED tube lamp as claimed in claim **31**, wherein the power supply comprises a circuit board disposed inside one of the end caps, and the connecting region electrically coupled to the circuit board.

34. The LED tube lamp as claimed in claim **33**, wherein the circuit board is parallel to a longitudinal direction of the lamp tube.

35. The LED tube lamp as claimed in claim **33**, wherein the circuit board is perpendicular to a longitudinal direction of the lamp tube.

36. The LED tube lamp as claimed in claim **31**, wherein the light strip further comprises a first wiring layer, wherein the protective layer covers a first side of the first wiring layer, and wherein the plurality of LED light sources are disposed on the first side of the first wiring layer and are electrically connected to the first wiring layer.

37. The LED tube lamp as claimed in claim **36**, wherein the light strip further comprises a second wiring layer disposed on a second side of the first wiring layer, and wherein the second wiring layer is made of metal.

38. The LED tube lamp as claimed in claim **37**, wherein the light strip further comprises a dielectric layer disposed between the first wiring layer and the second wiring layer.

39. The LED tube lamp as claimed in claim **29**, wherein at least one of the two end caps comprises at least one conductive pin electrically connected to with the power supply.

40. The LED tube lamp as claimed in claim **39**, wherein the LED tube lamp further comprises a diffusion film coated on a surface of the lamp tube.

41. The LED tube lamp as claimed in claim **40**, wherein the diffusion film is coated on an inner surface of the lamp tube.

42. The LED tube lamp as claimed in claim **40**, wherein the diffusion film comprises a sheet and covers without contacting with the LED light sources.

43. The LED tube lamp as claimed in claim **39**, further comprising a first pin and a second pin coupled to one of the two end caps, and a third pin coupled to the other end cap; and wherein the power supply comprises:

a first rectifying circuit connected to the first and second pins;

a second rectifying circuit connected to the third pin and an output terminal of the first rectifying circuit, wherein the first and second rectifying circuits are configured for rectifying an external driving signal to produce a rectified signal; and

a driving circuit coupled to the first and second rectifying circuits and the LED light sources and configured to drive the LED light sources,

wherein the LED tube lamp is configured to receive the external driving signal and emit light in one of two power supply arrangements, a first power supply arrangement being that the external driving signal is a low frequency signal input and transmitted through the first and second pins, and a second power supply arrangement being that the external driving signal is a low frequency signal input and transmitted through one of the first and second pins and through the third pin across the two ends of the lamp tube; and

wherein the LED tube lamp is configured such that when the external driving signal is a low frequency signal, the LED tube lamp causes the rectified signal to be used by the driving circuit for driving the LED light sources to emit light.

44. The LED tube lamp as claimed in claim **43**, wherein the external driving signal is a low frequency signal having a frequency between 0 and 60 Hz.

45. The LED tube lamp as claimed in claim **43**, wherein the first rectifying circuit comprises a first diode, a second diode, a third diode and a fourth diode, the first pin is connected to a first common node connecting an anode of the first diode and a cathode of the second diode, and the second pin is connected to a second common node connecting an anode of the third diode and a cathode of the fourth diode.

46. The LED tube lamp as claimed in claim **45**, wherein the second rectifying circuit comprises a fifth diode and a sixth diode and has a third common node connecting an anode of the fifth diode and a cathode of the sixth diode of the second rectifying circuit, and the third common node is coupled to the third pin; and a common anode of the second and the fourth diodes of the first rectifying circuit is coupled to an anode of one of the fifth and sixth diodes of the second rectifying circuit, and a common cathode of the first and third diodes of the first rectifying circuit is coupled to a cathode of the other one of the fifth and sixth diodes of the second rectifying circuit.

47. The LED tube lamp as claimed in claim **43**, wherein the LED tube lamp is configured such that the driving circuit does not drive the LED light sources to emit light, when an external driving signal input through one of the first and second pins and the third pin across the two ends of the lamp tube is provided by an electrical ballast.

48. The LED tube lamp as claimed in claim **47**, wherein when the external driving signal provided by an electrical ballast is input across the two ends of the lamp tube, the rectified signal bypasses at least a component of the driving circuit, and the driving circuit drives the LED light sources to emit light.

49. The LED tube lamp as claimed in claim **39**, further comprising a first pin and a second pin coupled to one of the two end caps, and a third pin coupled to the other end cap; and further wherein the power supply comprises:

a first rectifying circuit comprising diodes connected to the first and second pins;

a second rectifying circuit comprising diodes connected to the third pin and an output terminal of the first rectifying circuit, wherein the first and second rectifying circuits are configured to rectify an external driving signal to produce a rectified signal; and

a detection circuit coupled to the first and second rectifying circuits and the LED light sources, and configured to determine whether to cause the LED light sources to be driven by the rectified signal, or to prevent the LED light sources from being driven by the rectified signal,

wherein the LED tube lamp is configured to receive the external driving signal and emit light in each of two power supply arrangements, a first power supply arrangement being that the external driving signal is input and transmitted through the first and second pins, and a second power supply arrangement being that the external driving signal is input and transmitted through one of the first and second pins and through the third pin across the two ends of the lamp tube.

50. The LED tube lamp as claimed in claim **49**, wherein the power supply further comprises a driving circuit coupled to the first and second rectifying circuits and the LED light sources, and configured to drive the LED light sources.

51. The LED tube lamp as claimed in claim **50**, wherein when the external driving signal is a low frequency signal from an AC powerline, the LED tube lamp causes the rectified signal to be used by the driving circuit for driving the LED light sources to emit light.

52. The LED tube lamp as claimed in claim **50**, wherein the detection circuit comprises a mode switching circuit coupled to the first and second rectifying circuits and the driving circuit, and configured to cause the rectified signal to be used by the driving circuit when the external driving signal is a low frequency signal from an AC powerline.

53. The LED tube lamp as claimed in claim **49**, wherein the first rectifying circuit comprises four diodes, the first pin is connected to a first common node connecting an anode and a cathode respectively of two of the four diodes, and the second pin is connected to a second common node connecting an anode and a cathode respectively of the other two of the four diodes.

54. The LED tube lamp as claimed in claim **53**, wherein the second rectifying circuit comprises two diodes having a third common node connecting an anode and a cathode respectively of the two diodes of the second rectifying circuit, and the third common node is coupled to the third pin, and a common anode of two of the four diodes of the first rectifying circuit is coupled to an anode of one of the two diodes of the second rectifying circuit, and further wherein a common cathode of the other two of the four diodes of the first rectifying circuit is coupled to a cathode of the other one of the two diodes of the second rectifying circuit.

* * * * *

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(12) **United States Patent**
Jiang et al.

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(45) **Date of Patent: Jul. 16, 2019**

(54) **LED TUBE LAMP**

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(73) Assignee: **JIAXING SUPER LIGHTING ELECTRIC APPLIANCE CO., LTD**, Zhejiang (CN)

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(58) **Field of Classification Search**
CPC F21K 9/275; F21K 9/272; F21K 9/278; F21K 9/27; F21V 3/0615; F21V 3/10;
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Primary Examiner — Ali Alavi
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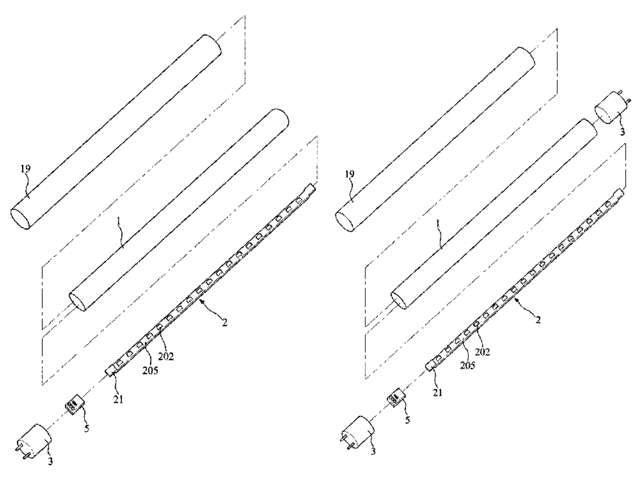
(57) **ABSTRACT**

An LED tube lamp including a glass lamp tube, an end cap disposed at one end of the glass lamp tube, a power supply provided inside the end cap, an LED light strip disposed inside the glass lamp tube with a plurality of LED light sources mounted on. At least a part of an inner surface of the glass lamp tube is formed with a rough surface, and the glass lamp tube is covered by a heat shrink sleeve. The LED light strip has a bendable circuit sheet which is made of a metal layer structure to electrically connect the LED light sources with the power supply. The glass lamp tube and the end cap are secured by a highly thermal conductive silicone gel with its thermal conductivity not less than 0.7 w/m·k.

23 Claims, 13 Drawing Sheets



Related U.S. Application Data

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(30) **Foreign Application Priority Data**

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Oct. 30, 2015	(CN)	2015 1 0726365
Dec. 2, 2015	(CN)	2015 1 0868263

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F21V 3/06	(2018.01)
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F21V 25/04	(2006.01)
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F21V 19/00	(2006.01)
F21K 9/27	(2016.01)
F21K 9/272	(2016.01)
F21K 9/275	(2016.01)
F21K 9/278	(2016.01)
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(58) **Field of Classification Search**

CPC F21V 3/02; F21V 3/0427; F21V 3/0472; F21V 17/101; F21V 31/005; F21V 23/00; F21V 29/83; F21V 3/061; F21V 7/005; F21V 15/015; F21V 19/009; F21V 23/02; F21V 23/023; F21V 25/04; F21Y 2103/10; F21Y 2115/10

See application file for complete search history.

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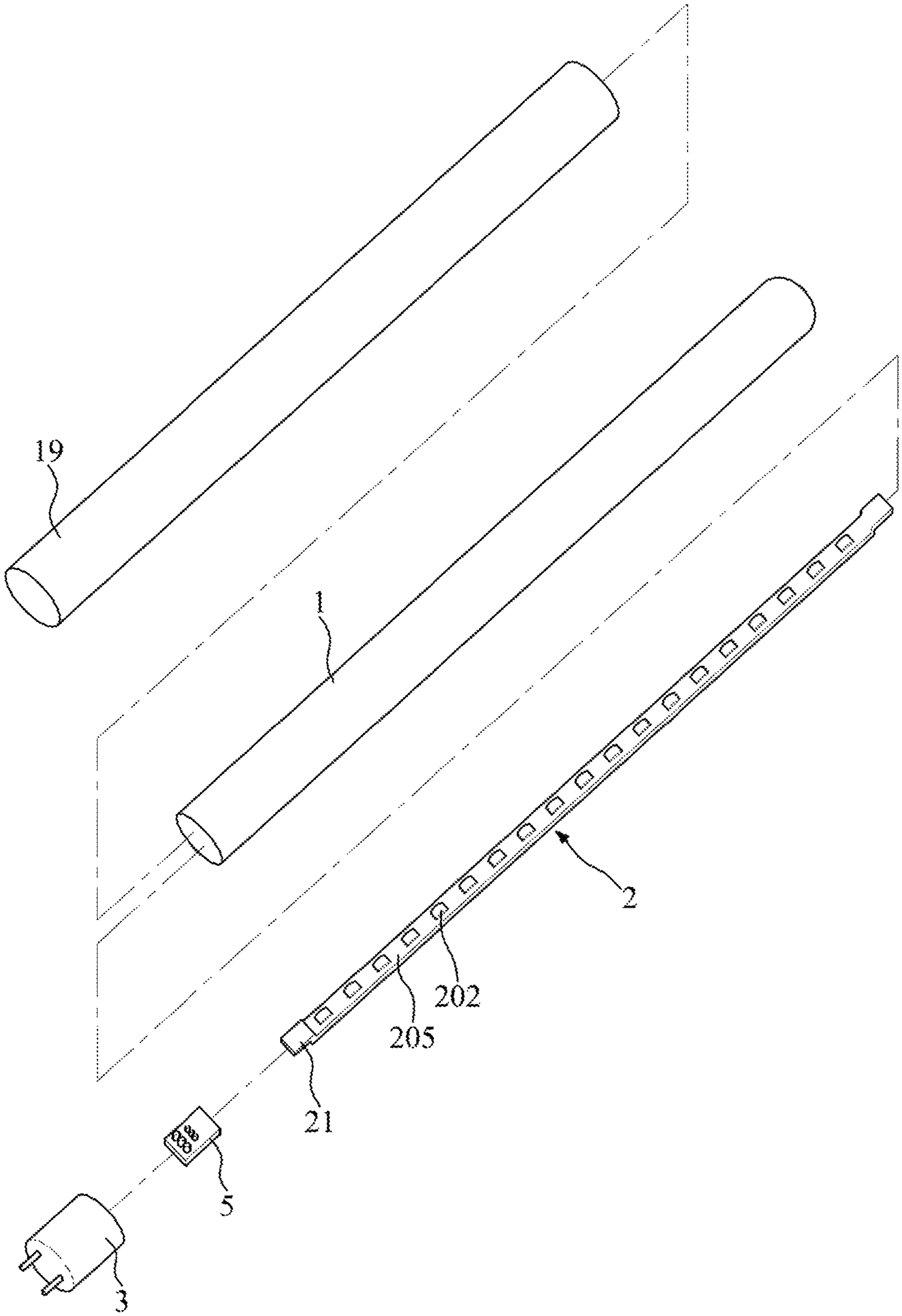

FIG.1A

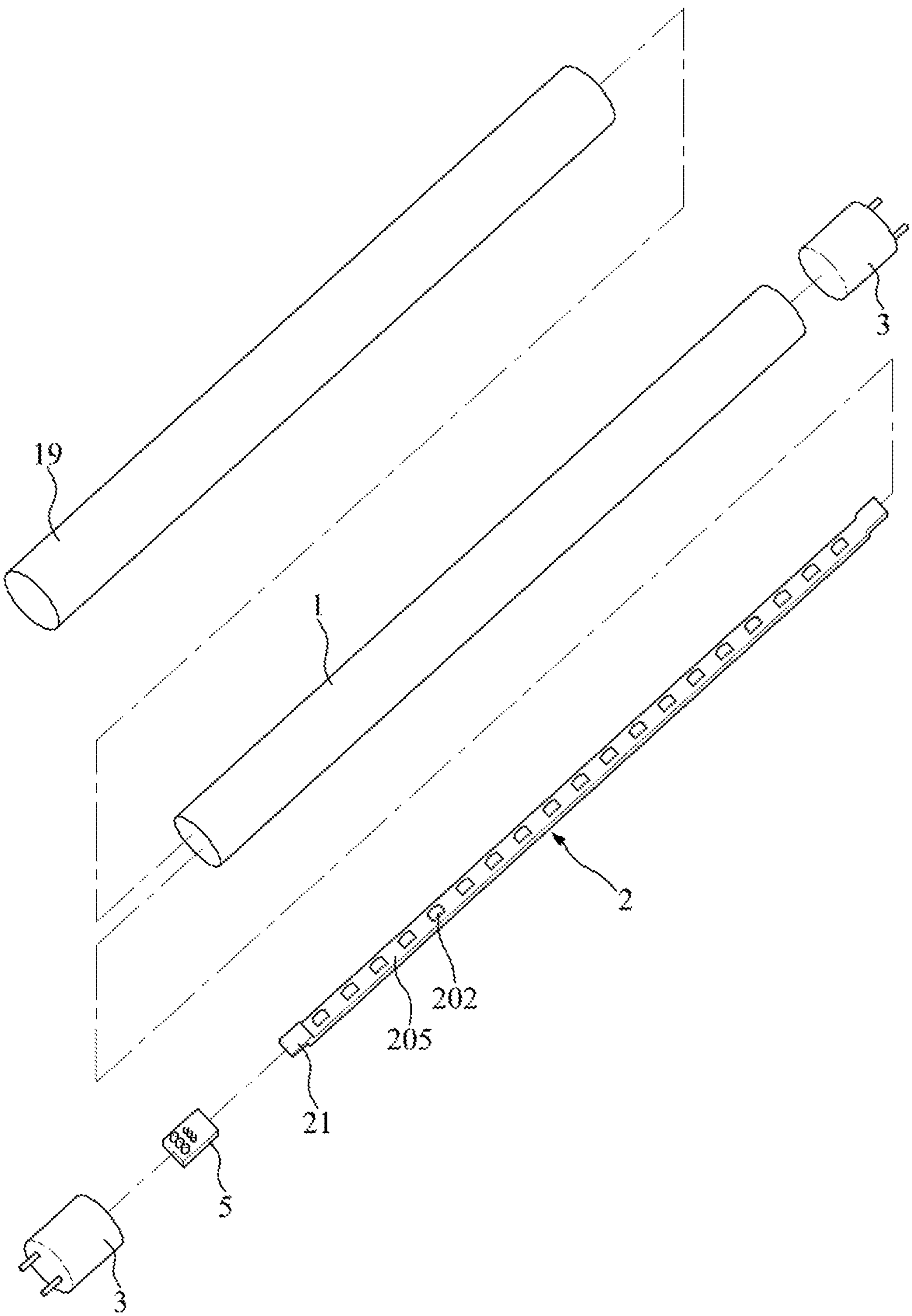

FIG.1B

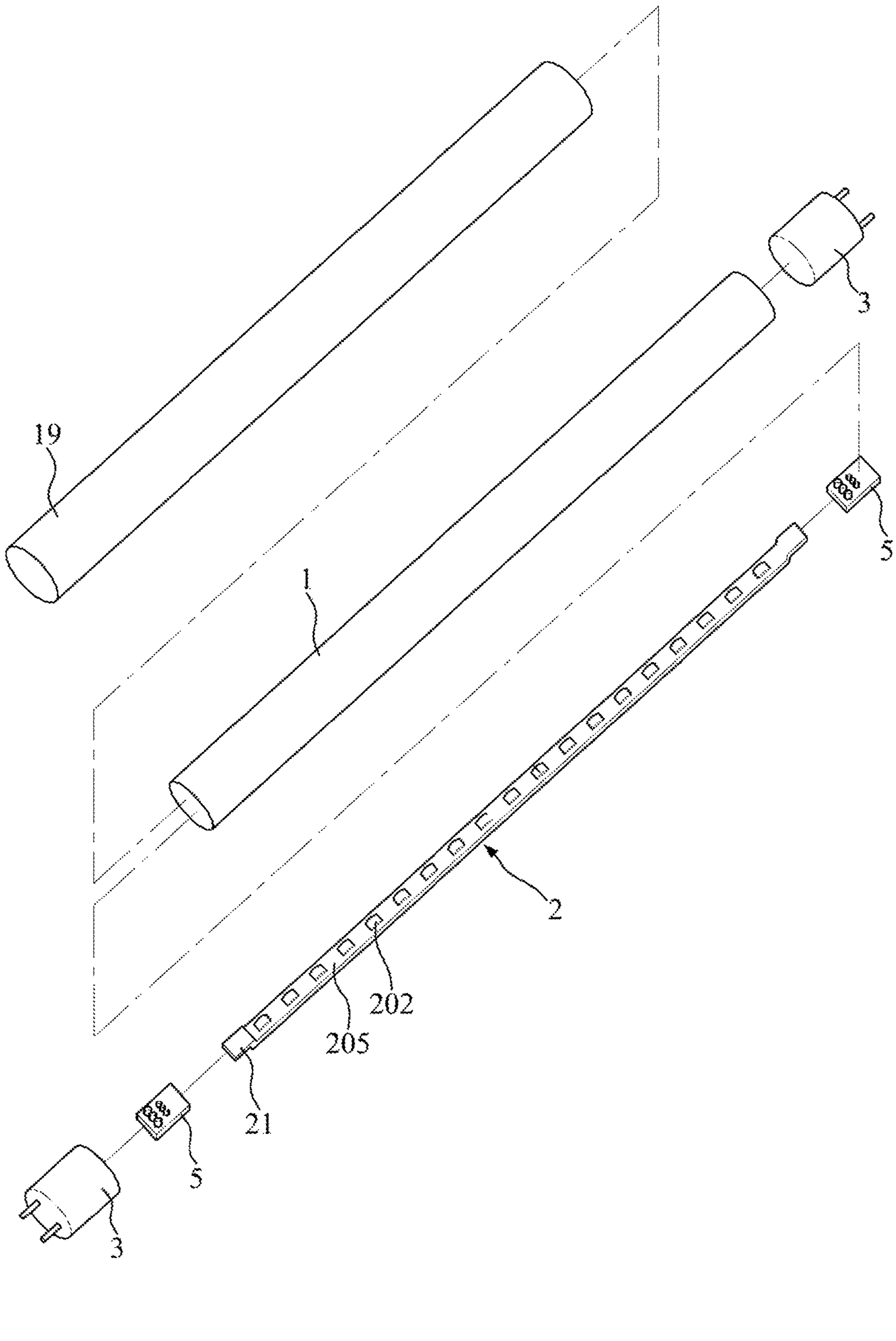

FIG.1C

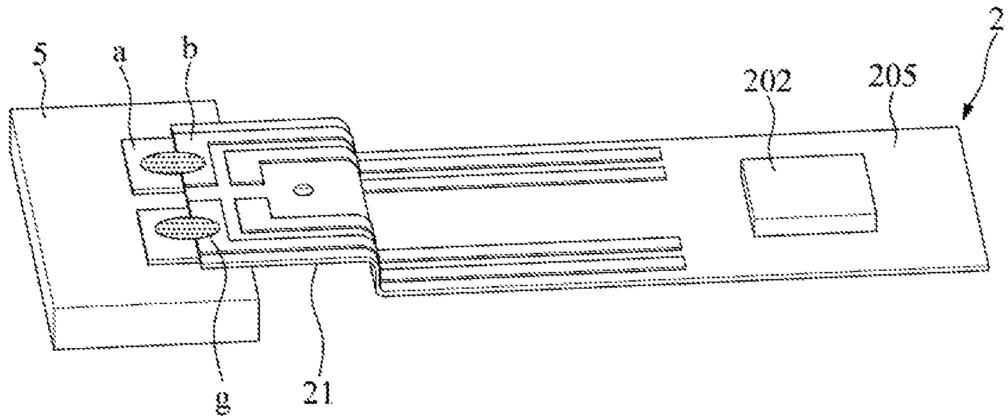

FIG.2

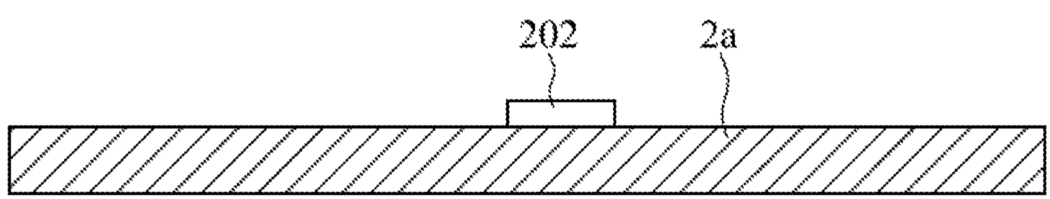

FIG.3

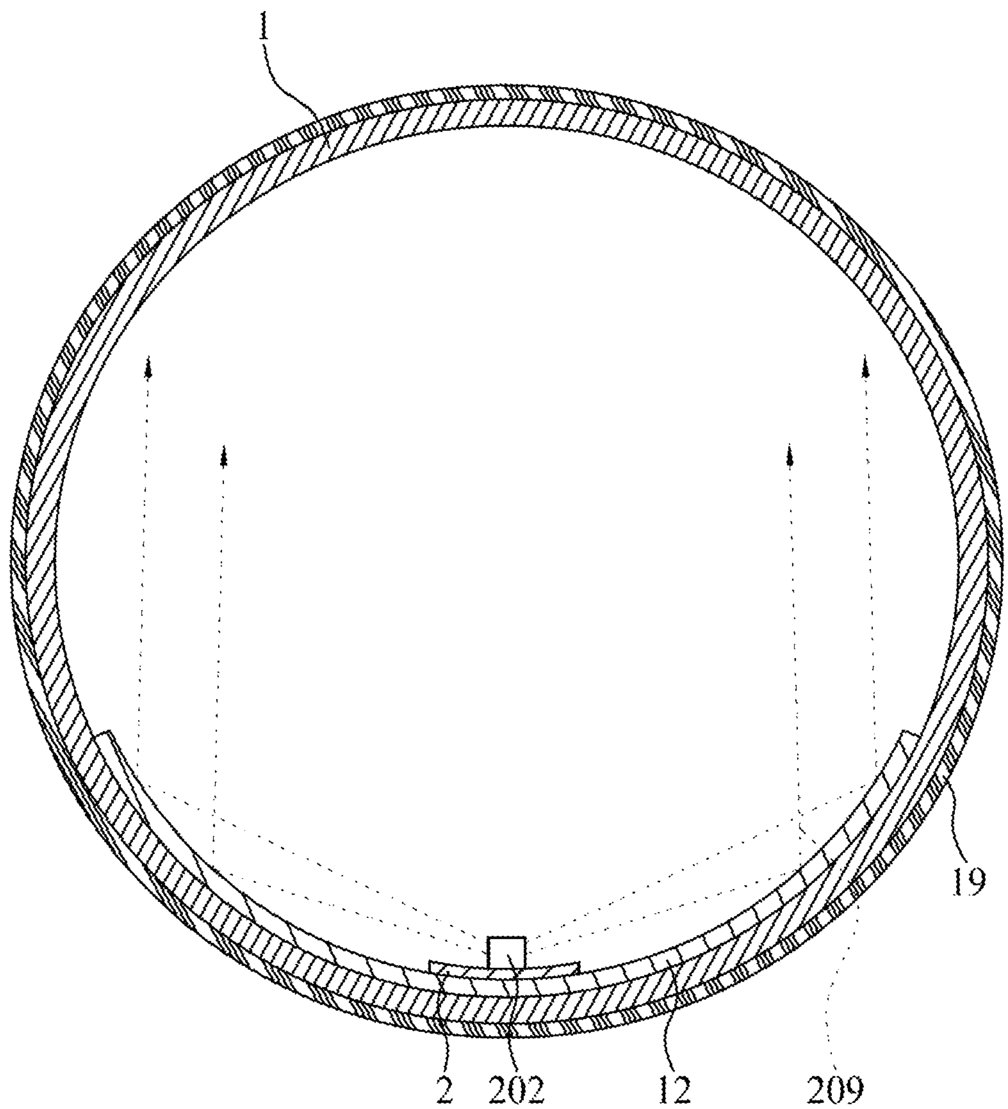

FIG.4

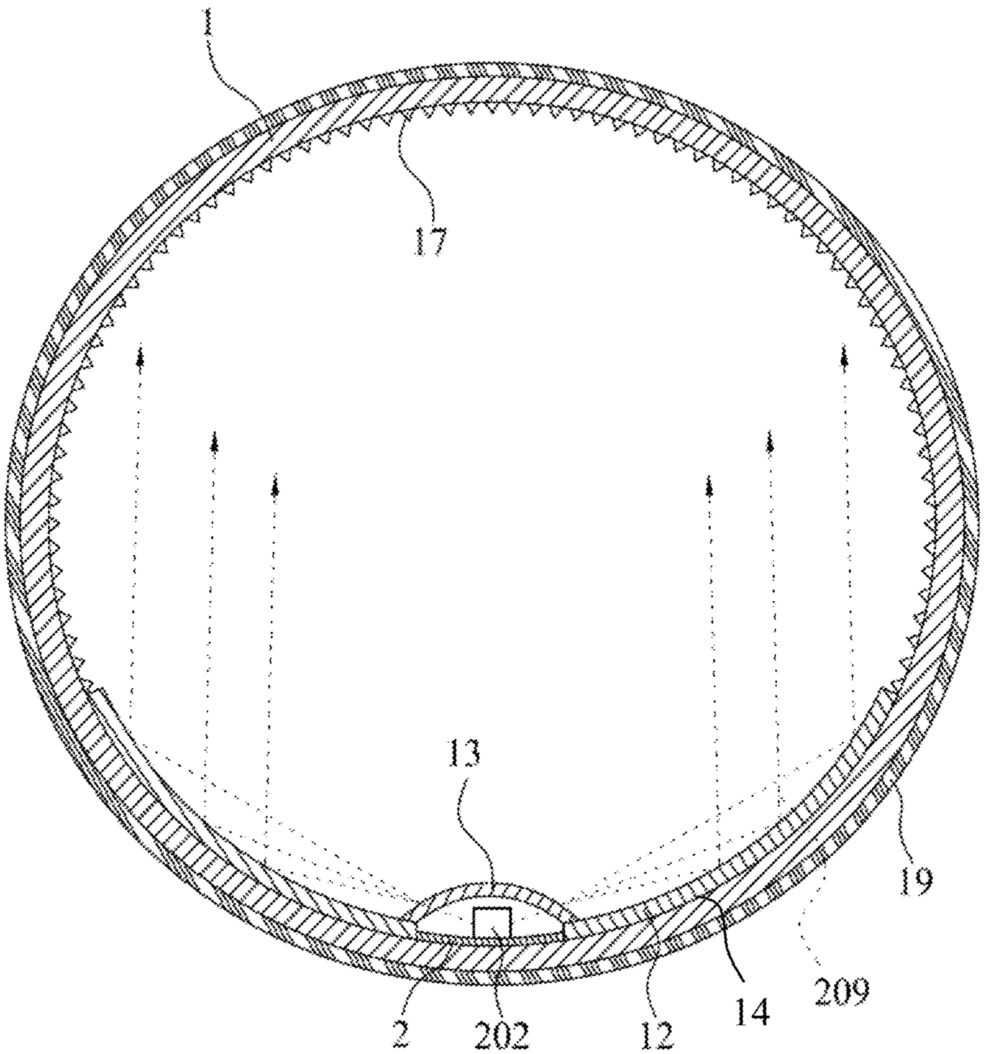

FIG. 5

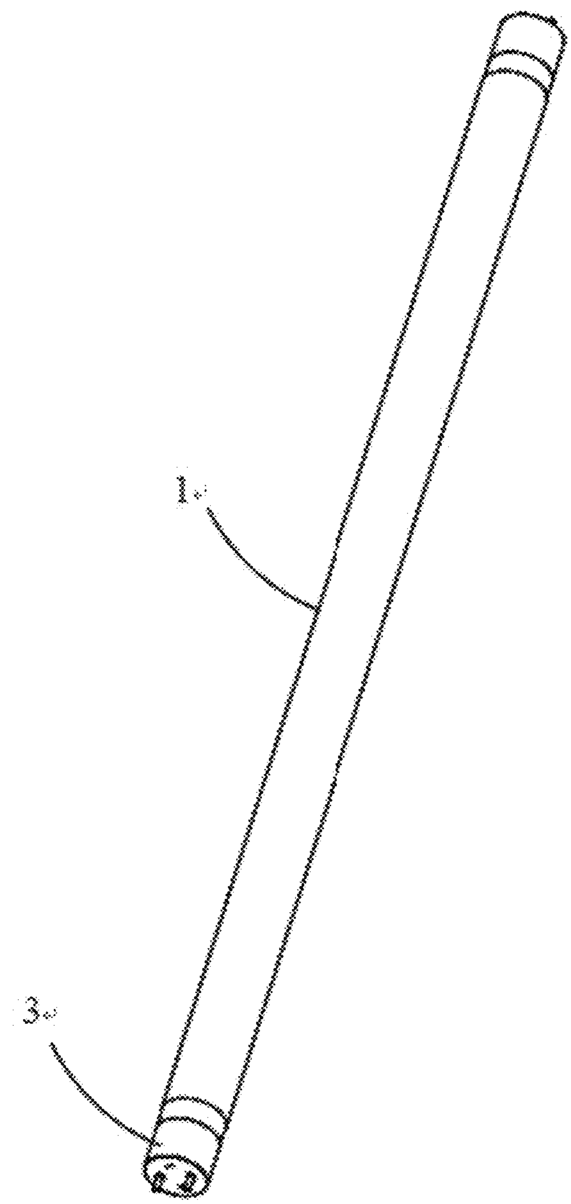

FIG. 6

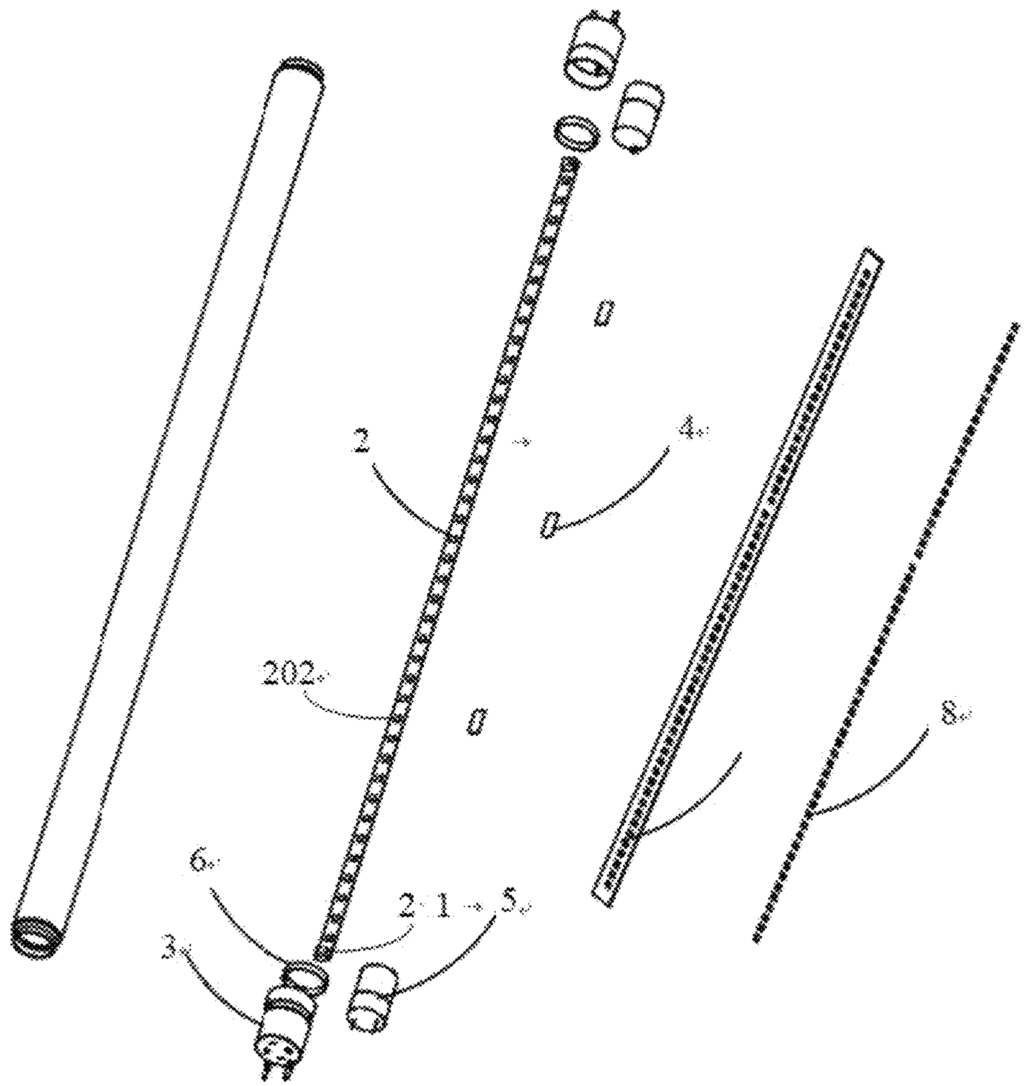

FIG. 7

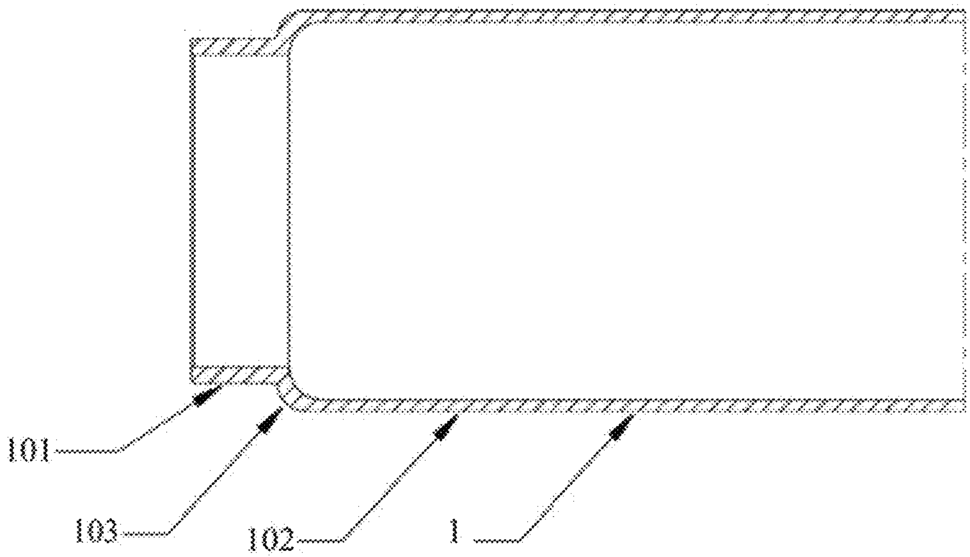

FIG. 8

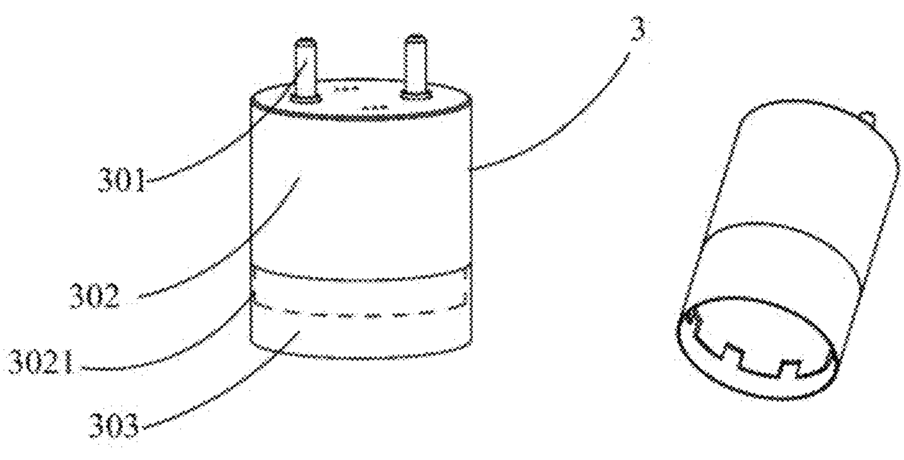

FIG. 9

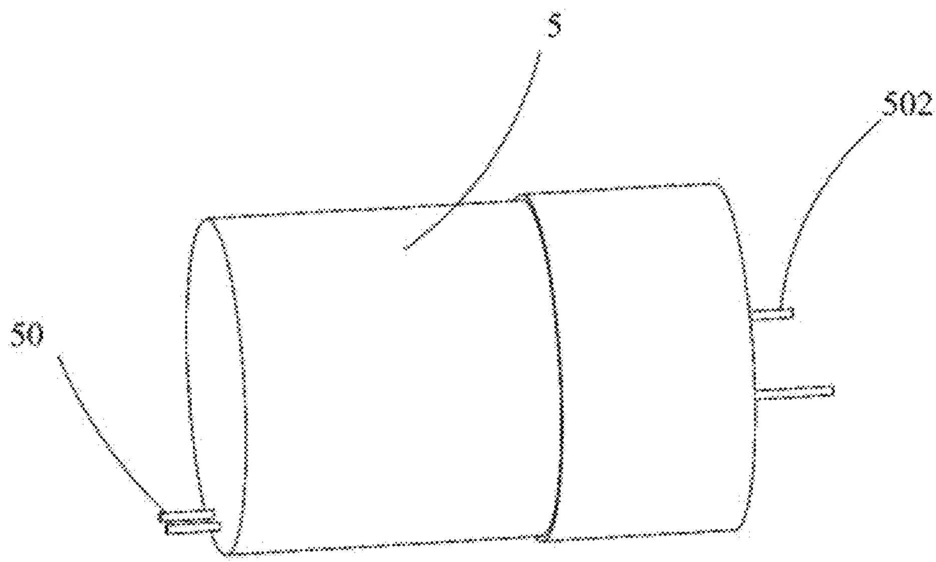

FIG. 10

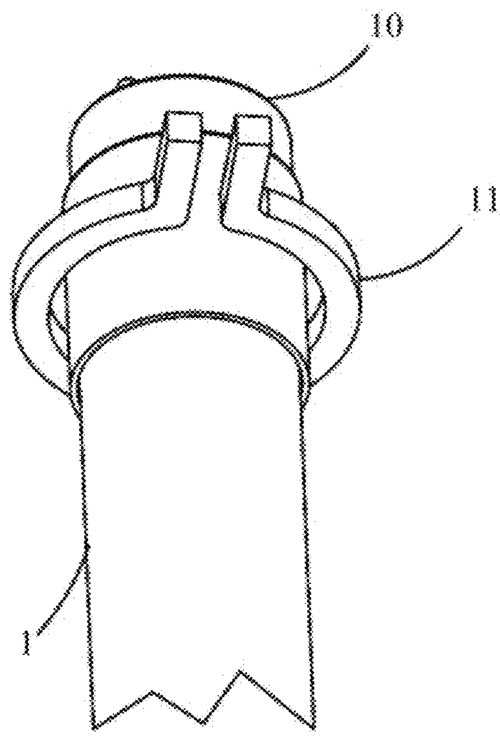

FIG. 11

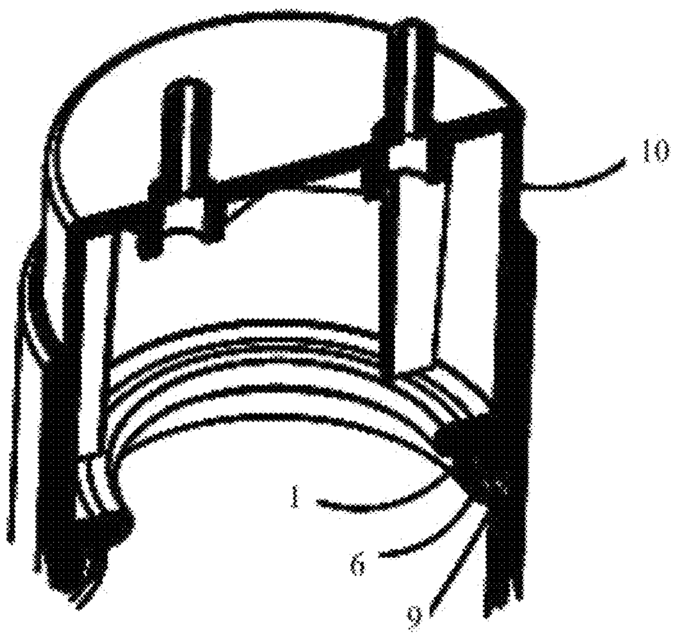

FIG. 12

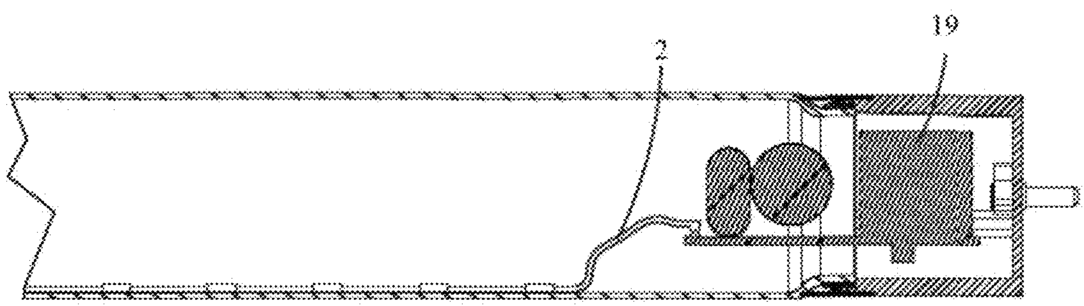

FIG. 13

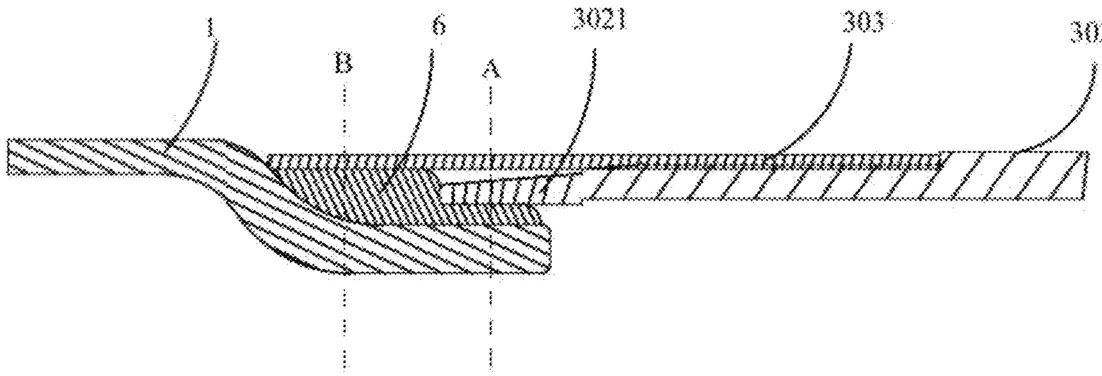

FIG. 14

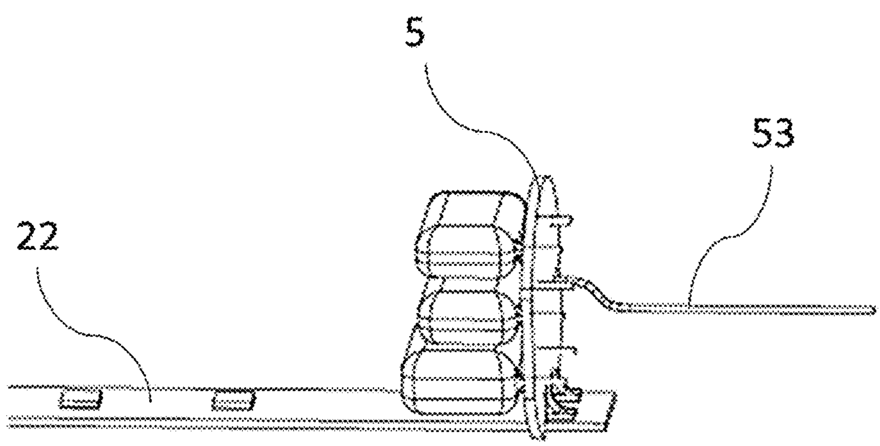

FIG. 15

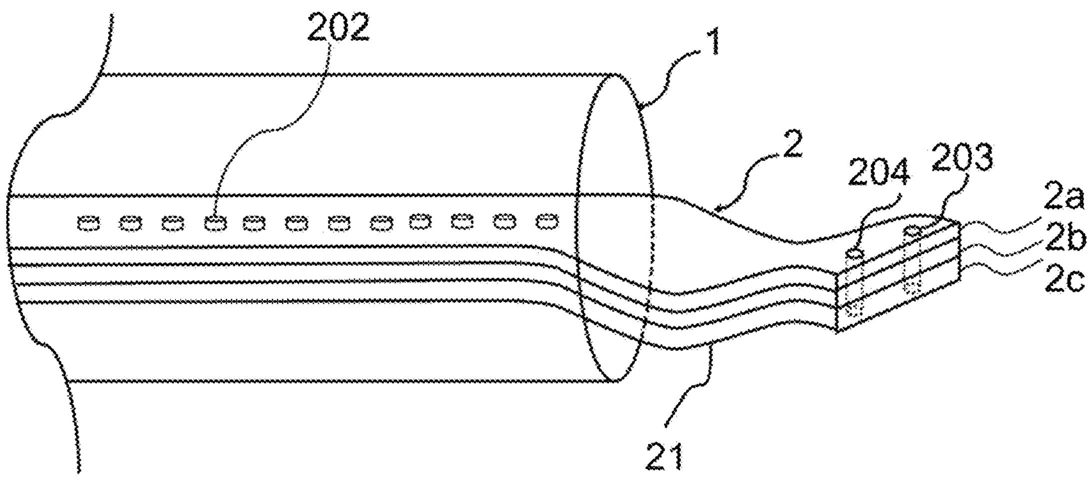

FIG. 16

LED TUBE LAMP

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation application claiming benefit of non-provisional application Ser. No. 15/056,106, filed on 2016 Feb. 29, which is a continuation-in-part application claiming benefit of PCT Application No. PCT/CN2015/096502, filed on 2015 Dec. 5, which claims priority to Chinese Patent Applications No. CN 201410734425.5 filed on 2014 Dec. 5; CN 201510075925.7 filed on 2015 Feb. 12; CN 201510136796.8 filed on 2015 Mar. 27; CN 201510259151.3 filed on 2015 May 19; CN 201510324394.0 filed on 2015 Jun. 12; CN 201510338027.6 filed on 2015 Jun. 17; CN 201510373492.3 filed on 2015 Jun. 26; CN 201510448220.5 filed on 2015 Jul. 27; CN 201510482944.1 filed on 2015 Aug. 7; CN 201510483475.5 filed on 2015 Aug. 8; CN 201510499512.1 filed on 2015 Aug. 14; CN 201510555543.4 filed on 2015 Sep. 2; CN 201510645134.3 filed on 2015 Oct. 8; CN 201510716899.1 filed on 2015 Oct. 29, and CN 201510868263.9 filed on 2015 Dec. 2, the disclosures of which are incorporated herein in their entirety by reference.

FIELD OF THE INVENTION

The present disclosure relates to illumination devices, and more particularly to an LED tube lamp and its components including the light sources, electronic components, and end caps.

BACKGROUND OF THE INVENTION

LED lighting technology is rapidly developing to replace traditional incandescent and fluorescent lightings. LED tube lamps are mercury-free in comparison with fluorescent tube lamps that need to be filled with inert gas and mercury. Thus, it is not surprising that LED tube lamps are becoming a highly desired illumination option among different available lighting systems used in homes and workplaces, which used to be dominated by traditional lighting options such as compact fluorescent light bulbs (CFLs) and fluorescent tube lamps. Benefits of LED tube lamps include improved durability and longevity and far less energy consumption; therefore, when taking into account all factors, they would typically be considered as a cost effective lighting option.

Typical LED tube lamps have a lamp tube, a circuit board disposed inside the lamp tube with light sources being mounted on the circuit board, and end caps accompanying a power supply provided at two ends of the lamp tube with the electricity from the power supply transmitting to the light sources through the circuit board. However, existing LED tube lamps have certain drawbacks.

First, the typical circuit board is rigid and allows the entire lamp tube to maintain a straight tube configuration when the lamp tube is partially ruptured or broken, and this gives the user a false impression that the LED tube lamp remains usable and is likely to cause the user to be electrically shocked upon handling or installation of the LED tube lamp.

Second, the rigid circuit board is typically electrically connected with the end caps by way of wire bonding, in which the wires may be easily damaged and even broken due to any move during manufacturing, transportation, and usage of the LED tube lamp and therefore may disable the LED tube lamp.

Third, grainy visual appearances are also often found in the aforementioned typical LED tube lamp. The LED chips spatially arranged on the circuit board inside the lamp tube are considered as spot light sources, and the lights emitted from these LED chips generally do not contribute uniform illuminance for the LED tube lamp without proper optical manipulation. As a result, the entire tube lamp would exhibit a grainy or non-uniform illumination effect to a viewer of the LED tube lamp, thereby negatively affecting the visual comfort and even narrowing the viewing angles of the lights. As a result, the quality and aesthetics requirements of average consumers would not be satisfied. To address this issue, the Chinese patent application with application no. CN 201320748271.6 discloses a diffusion tube is disposed inside a glass lamp tube to avoid grainy visual effects.

However, the disposition of the diffusion tube incurs an interface on the light transmission path to increase the likelihood of total reflection and therefore decrease the light outputting efficiency. In addition, the optical rotatory absorption of the diffusion tube decreases the light outputting efficiency.

Moreover, there is another technology used in the field of LED chip manufacturing for improving output of light by surface roughening as disclosed in the Master Thesis of Mr. Chen. This thesis describes the surface texturization of p-GaN, LED chip, surface using a combination of Ni natural lithography and wet etching techniques. (Please see Hsin-Hung Chan, "Improved Light Output and Electrical Performance of GaN-Based Light-Emitting Diodes by Surface Roughening", Master thesis, Graduate Institute of Precision Engineering, National Chung-Hsing University, Taiwan R.O.C. (2006)).

In addition, the LED tube lamp may be supplied with electrical power from two end caps respectively disposed at two ends of the glass lamp tube of the LED tube lamp and a user may be electrically shocked when he installs the LED tube lamp to a lamp holder and touches the metal parts or the electrically conductive parts which are still exposed.

Accordingly, the prevent disclosure and its embodiments are herein provided.

SUMMARY OF THE INVENTION

It's specially noted that the present disclosure may actually include one or more inventions claimed currently or not yet claimed, and for avoiding confusion due to unnecessarily distinguishing between those possible inventions at the stage of preparing the specification, the possible plurality of inventions herein may be collectively referred to as "the (present) invention" herein.

Various embodiments are summarized in this section, and are described with respect to the "present invention," which terminology is used to describe certain presently disclosed embodiments, whether claimed or not, and is not necessarily an exhaustive description of all possible embodiments, but rather is merely a summary of certain embodiments. Certain of the embodiments described below as various aspects of the "present invention" can be combined in different manners to form an LED tube lamp or a portion thereof.

The present invention provides a novel LED tube lamp, and aspects thereof.

The present invention provides an LED tube lamp. According to one embodiment, the LED lamp includes a glass lamp tube, an end cap, a power supply, and an LED light strip. The glass lamp tube is covered by a heat shrink sleeve. A thickness of the heat shrink sleeve is between 20 μm and 200 μm. At least a part of an inner surface of the glass lamp tube is formed with a rough surface and the roughness of the inner surface is higher than that of an outer surface of the glass lamp tube. The end cap is disposed at one end of the glass lamp tube. The power supply is provided inside the end cap. The LED light strip is disposed inside the glass lamp tube with a plurality of LED light sources mounted on the LED light strip. The LED light strip has a bendable circuit sheet which is made of a metal layer structure and mounted on the inner surface of the glass lamp tube to electrically connect the LED light sources with the power supply. The length of the bendable circuit sheet is larger than the length of the glass lamp tube. The glass lamp tube and the end cap are secured by a highly thermal conductive silicone gel.

In some embodiments, the thermal conductivity of the highly thermal conductive silicone gel may be not less than 0.7 w/m·k.

In some embodiments, the thickness of the metal layer structure may range from 10 μm to 50 μm.

In some embodiments, the metal layer structure may be a patterned wiring layer.

In some embodiments, the roughness of the inner surface may range from 0.1 to 40 μm.

In some embodiments, the glass lamp tube may be coated with an anti-reflection layer with a thickness of one quarter of the wavelength range of light coming from the LED light source.

In some embodiments, the refractive index of the anti-reflection layer may be a square root of the refractive index of the glass lamp tube with a tolerance of ±20%.

In some embodiments, the bendable circuit sheet may have its ends extending beyond two ends of the glass lamp tube to respectively form two freely extending end portions.

In some embodiments, the LED tube lamp further may include one or more reflective films to reflect light from the plurality of LED light sources.

In some embodiments, the glass lamp tube may further include a diffusion film so that the light emitted from the plurality of LED light sources is transmitted through the diffusion film and the glass lamp tube.

In some embodiments, the glass lamp tube may be covered with an adhesive film.

The present invention also provides an LED tube lamp, according to one embodiment, includes a glass lamp tube, an end cap, a power supply, and an LED light strip. At least a part of an inner surface of the glass lamp tube is formed with a rough surface and a roughness of the inner surface is higher than that of the outer surface. The end cap is disposed at one end of the glass lamp tube. The power supply is provided inside the end cap. The LED light strip is disposed inside the glass lamp tube with a plurality of LED light sources mounted on the LED light strip. The LED light strip has a bendable circuit sheet mounted on an inner surface of the glass lamp tube to electrically connect the LED light sources with the power supply. The length of the bendable circuit sheet is larger than the length of the glass lamp tube. The glass lamp tube and the end cap are secured by a highly thermal conductive silicone gel.

The present invention also provides an LED tube lamp, according to one embodiment, includes a glass lamp tube, an end cap, a power supply, and an LED light strip. The glass lamp tube is covered by a heat shrink sleeve. The inner surface of the glass lamp tube is formed with a rough surface, the roughness of the inner surface is higher than that of the outer surface, and the roughness of the inner surface ranges from 0.1 to 40 μm. The end cap is disposed at one end of the glass lamp tube. The power supply is provided inside

the end cap. The LED light strip is disposed inside the glass lamp tube with a plurality of LED light sources mounted on the LED light strip. The LED light strip has a bendable circuit sheet which is made of a metal layer structure and mounted on an inner surface of the glass lamp tube to electrically connect the LED light sources with the power supply. The length of the bendable circuit sheet is larger than the length of the glass lamp tube. The glass lamp tube and the end cap are secured by a highly thermal conductive silicone gel.

The rough surface and the roughness of the inner surface of the glass lamp tube can make the light from the LED light sources be uniform when transmitting through the glass lamp tube.

The heat shrink sleeve is capable of making the glass lamp tube electrically insulated. The heat shrink sleeve may be substantially transparent with respect to the wavelength of light from the LED light sources, such that only a slight part of the lights transmitting through the glass lamp tube is absorbed by the heat shrink sleeve. If the thickness of the heat shrink sleeve is between 20 μm to 200 μm, the light absorbed by the heat shrink sleeve is negligible.

The highly thermal conductive silicone gel has excellent weatherability and can prevent moisture from entering inside of the glass lamp tube, which improves the durability and reliability of the LED tube lamp.

The anti-reflection layer is capable of reducing the reflection occurring at an interface between the glass lamp tube's inner surface and the air, which allows more light from the LED light sources transmit through the glass lamp tube.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**A is an exploded view schematically illustrating the LED tube lamp according to one embodiment of the present invention, wherein the glass lamp tube has only one inlets located at its one end while the other end is entirely sealed or integrally formed with tube body;

FIG. **1**B is an exploded view schematically illustrating the LED tube lamp according to one embodiment of the present invention, wherein the glass lamp tube has two inlets respectively located at its two ends;

FIG. **1**C is an exploded view schematically illustrating the LED tube lamp according to one embodiment of the present invention, wherein the glass lamp tube has two inlets respectively located at its two ends, and two power supplies are respectively disposed in two end caps;

FIG. **2** is a perspective view schematically illustrating the soldering pad of the bendable circuit sheet of the LED light strip for soldering connection with the printed circuit board of the power supply of the LED tube lamp according to one embodiment of the present invention;

FIG. **3** is a plane cross-sectional view schematically illustrating a single-layered structure of the bendable circuit sheet of the LED light strip of the LED tube lamp according to an embodiment of the present invention;

FIG. **4** is a plane cross-sectional view schematically illustrating inside structure of the glass lamp tube of the LED tube lamp according to one embodiment of the present invention, wherein two reflective films are respectively adjacent to two sides of the LED light strip along the circumferential direction of the glass lamp tube;

FIG. **5** is a plane cross-sectional view schematically illustrating inside structure of the glass lamp tube of the LED tube lamp according to one embodiment of the present invention, wherein two reflective films are respectively adjacent to two sides of the LED light strip along the circumferential direction of the glass lamp tube and a diffusion film is disposed covering the LED light sources;

FIG. **6** is a three dimensional schematic view of an LED tube lamp according to an embodiment of the invention;

FIG. **7** is an exploded view of an LED tube lamp according to an embodiment of the invention;

FIG. **8** is a cross sectional schematic view of a housing of an LED tube lamp according to an embodiment of the invention;

FIG. **9** is a three dimensional schematic view of an end cap of an LED tube lamp according to an embodiment of the invention;

FIG. **10** is a three dimensional schematic view of a power of an LED tube lamp according to an embodiment of the invention;

FIG. **11** is a schematic view showing a plastic end cap assembled to a housing of a glass tube sleeved with an induction ring;

FIG. **12** is a cross sectional view of the plastic end cap of FIG. **6**;

FIG. **13** is a schematic view showing a LED light strip being a flexible substrate directly soldered on an end of the power;

FIG. **14** is a cross sectional view showing the relation of the end cap and the housing after installation;

FIG. **15** is a perspective view schematically illustrating the printed circuit board of the power supply is perpendicularly adhered to a hard circuit board made of aluminum via soldering according to another embodiment of the present invention; and

FIG. **16** is a perspective view schematically illustrating the bendable circuit sheet of the LED light strip is formed with two conductive wiring layers according to another embodiment of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

The present disclosure provides a novel LED tube lamp based on the glass made lamp tube to solve the abovementioned problems. The present disclosure will now be described in the following embodiments with reference to the drawings. The following descriptions of various embodiments of this invention are presented herein for purpose of illustration and giving examples only. It is not intended to be exhaustive or to be limited to the precise form disclosed. These example embodiments are just that—examples—and many implementations and variations are possible that do not require the details provided herein. It should also be emphasized that the disclosure provides details of alternative examples, but such listing of alternatives is not exhaustive. Furthermore, any consistency of detail between various examples should not be interpreted as requiring such detail—it is impracticable to list every possible variation for every feature described herein. The language of the claims should be referenced in determining the requirements of the invention.

"Terms such as "about" or "approximately" may reflect sizes, orientations, or layouts that vary only in a small relative manner, and/or in a way that does not significantly alter the operation, functionality, or structure of certain elements. For example, a range from "about 0.1 to about 1" may encompass a range such as a 0% to 5% deviation around 0.1 and a 0% to 5% deviation around 1, especially if such deviation maintains the same effect as the listed range."

"Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as

commonly understood by one of ordinary skill in the art to which this disclosure belongs. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and/or the present application, and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein."

Referring to FIG. **1**A, FIG. **1**B, and FIG. **1**C, an LED tube lamp in accordance with a first embodiment of the present invention includes a glass lamp tube **1**, an LED light strip **2** disposed inside the glass lamp tube **1**, and one end cap **3** disposed at one end of the glass lamp tube **1**. Each of the end caps **3** has at least one pin. As shown in FIG. **1**A, FIG. **1**B, and FIG. **1**C, there are two pins on each end cap **3** to be connected with an outer electrical power source. In this embodiment, as shown in FIG. **1**A, the glass lamp tube **1** may have only one inlet located at one end while the other end is entirely sealed or integrally formed with tube body. The LED light strip **2** is disposed inside the glass lamp tube **1** with a plurality of LED light sources **202** mounted on the LED light strip **2**. The end cap **3** is disposed at the end of the glass lamp tube **1** where the inlet located, and the power supply **5** is provided inside the end cap **3**. In another embodiment, as shown in FIG. **1**B, the glass lamp tube **1** may have two inlets, two end caps **3** respectively disposed at two ends of the glass lamp tube **1**, and one power supply **5** provided inside one of the end caps **3**. In another embodiment, as shown in FIG. **1**C, the glass lamp tube **1** may have two inlets, two end caps **3** respectively disposed at two ends of the glass lamp tube **1**, and two power supplies **5** respectively provided inside the two end caps **3**.

The glass lamp tube **1** is covered by a heat shrink sleeve **19**. The thickness of the heat shrink sleeve **19** may range from 20 μm to 200 μm. The heat shrink sleeve **19** is substantially transparent with respect to the wavelength of light from the LED light sources **202** such that only a slight part of the lights transmitting through the glass lamp tube is absorbed by the heat shrink sleeve **19**. The heat shrink sleeve **19** may be made of PFA (perfluoroalkoxy) or PTFE (poly tetra fluoro ethylene). Since the thickness of the heat shrink sleeve **19** is only 20 μm to 200 μm, the light absorbed by the heat shrink sleeve **19** is negligible. At least a part of the inner surface of the glass lamp tube **1** is formed with a rough surface and the roughness of the inner surface is higher than that of the outer surface, such that the light from the LED light sources **202** can be uniformly spread when transmitting through the glass lamp tube **1**. In some embodiments, the roughness of the inner surface of the glass lamp tube **1** may range from 0.1 μm to 40 μm.

The glass lamp tube **1** and the end cap **3** are secured by a highly thermal conductive silicone gel disposed between an inner surface of the end cap **3** and outer surfaces of the glass lamp tube **1**. In some embodiments, the highly thermal conductive silicone gel has a thermal conductivity not less than 0.7 w/m·k. In some embodiments, the thermal conductivity of the highly thermal conductive silicone gel is not less than 2 w/m·k. In some embodiments, the highly thermal conducive silicone gel is of high viscosity, and the end cap **3** and the end of the glass lamp tube **1** could be secured by using the highly thermal conductive silicone gel and therefore qualified in a torque test of 1.5 to 5 newton-meters (Nt-m) and/or in a bending test of 5 to 10 newton-meters (Nt-m). The highly thermal conductive silicone gel has excellent weatherability and can prevent moisture from entering inside of the glass lamp tube **1**, which improves the durability and reliability of the LED tube lamp.

Referring to FIG. **1**A, FIG. **1**B, FIG. **1**C, and FIG. **2**, the LED light strip **2** has a bendable circuit sheet **205** mounted on the inner surface of the glass lamp tube **1**.

The bendable circuit sheet **205** electrically connects the LED light sources **202** with the power supply **5**, and the length of the bendable circuit sheet **205** is larger than the length of the glass lamp tube **1**. The bendable circuit sheet **205** has its ends extending beyond two ends of the glass lamp tube **1** to respectively form two freely extending end portions **21**. As shown in FIG. **2**, in which only one freely extending end portion **21** is illustrated, the freely extending end portion **21** is electrically connected to the power supply **5**. Specifically, the power supply **5** has soldering pads "a" which are capable of being soldered with the soldering pads "b" of the freely extending end portion **21** by soldering material "g".

Referring to FIG. **3**, the bendable circuit sheet **205** is made of a metal layer structure **2***a*. The thickness range of the metal layer structure **2***a* ma be 10 μm to 50 μm and the metal layer structure **2***a* may be a patterned wiring layer.

In some embodiments, the inner surface of the glass lamp tube **1** is coated with an anti-reflection layer with a thickness of one quarter of the wavelength range of light coming from the LED light sources **202**. With the anti-reflection layer, more light from the LED light sources **202** can transmit through the glass lamp tube **1**. In some embodiments, the refractive index of the anti-reflection layer is a square root of the refractive index of the glass lamp tube **1** with a tolerance of ±20%.

Referring to FIG. **4**, in some embodiments, the glass lamp tube **1** may further include one or more reflective films **12** disposed on the inner surface of the glass lamp tube **1**. The reflective film **12** can be positioned on two sides of the LED light strip **2**. And in some embodiments, a ratio of a length of the reflective film **12** disposed on the inner surface of the glass lamp tube **1** extending along the circumferential direction of the glass lamp tube **1** to a circumferential length of the glass lamp tube **1** may be about 0.3 to 0.5, which means about 30% to 50% of the inner surface area may be covered by the reflective film(s) **12**. The reflective film **12** may be made of PET with some reflective materials such as strontium phosphate or barium sulfate or any combination thereof, with a thickness between about 140 μm and about 350 μm or between about 150 μm and about 220 μm for a more preferred effect in some embodiments. In some embodiments, only the part of the inner surface which is not covered by the reflective film **12** is formed with the rough surface. As shown in FIG. **4**, a part of light **209** from LED light sources **202** are reflected by two reflective films **12** such that the light **209** from the LED light sources **202** can be centralized to a determined direction.

Referring to FIG. **5**, in some embodiments, the glass lamp tube **1** may further include a diffusion film **13** so that the light emitted from the plurality of LED light sources **202** is transmitted through the diffusion film **13** and the glass lamp tube **1**. The diffusion film **13** can be in form of various types, such as a coating onto the inner wall or outer wall of the glass lamp tube **1**, or a diffusion coating layer (not shown) coated at the surface of each LED light sources **202**, or a separate membrane covering the LED light sources **202**. The glass lamp tube **1** also includes a heat shrink sleeve **19** and a plurality of inner roughness **17**.

As shown in FIG. **5**, the diffusion film **13** is in form of a sheet, and it covers but not in contact with the LED light sources **202**. In some embodiments, the diffusion film **13** can be disposed on the inner surface or the outer surface of the lamp tube. The diffusion film **13** in form of a sheet is usually called an optical diffusion sheet or board, usually a composite made of mixing diffusion particles into polystyrene (PS), polymethyl methacrylate (PMMA), polyethylene terephthalate (PET), and/or polycarbonate (PC), and/or any combination thereof. The light passing through such composite is diffused to expand in a wide range of space such as a light emitted from a plane source, and therefore makes the brightness of the LED tube lamp uniform.

The diffusion film **13** may be in form of an optical diffusion coating, which is composed of any one of calcium carbonate, halogen calcium phosphate and aluminum oxide, or any combination thereof. When the optical diffusion coating is made from a calcium carbonate with suitable solution, an excellent light diffusion effect and transmittance to exceed 90% can be obtained.

In some embodiments, the composition of the diffusion film **13** in form of the optical diffusion coating may include calcium carbonate, strontium phosphate, thickener, and a ceramic activated carbon. Specifically, such an optical diffusion coating on the inner circumferential surface of the glass lamp tube **1** has an average thickness ranging from about 20 to about 30 μm. A light transmittance of the diffusion film **13** using this optical diffusion coating may be about 90%. Generally speaking, the light transmittance of the diffusion film **13** may range from 85% to 96%. In addition, this diffusion film **13** can also provide electrical isolation for reducing risk of electric shock to a user upon breakage of the glass lamp tube **1**. Furthermore, the diffusion film **13** provides an improved illumination distribution uniformity of the light outputted by the LED light sources **202** such that the light can illuminate the back of the light sources **202** and the side edges of the bendable circuit sheet **205** so as to avoid the formation of dark regions inside the glass lamp tube **1** and improve the illumination comfort. In another possible embodiment, the light transmittance of the diffusion film can be 92% to 94% while the thickness ranges from about 200 to about 300 μm.

In another embodiment, the optical diffusion coating can also be made of a mixture including calcium carbonate-based substance, some reflective substances like strontium phosphate or barium sulfate, a thickening agent, ceramic activated carbon, and deionized water. The mixture is coated on the inner circumferential surface of the glass lamp tube **1** and may have an average thickness ranging from about 20 to about 30 μm. In view of the diffusion phenomena in microscopic terms, light is reflected by particles. The particle size of the reflective substance such as strontium phosphate or barium sulfate will be much larger than the particle size of the calcium carbonate. Therefore, adding a small amount of reflective substance in the optical diffusion coating can effectively increase the diffusion effect of light.

Halogen calcium phosphate or aluminum oxide can also serve as the main material for forming the diffusion film **13**. The particle size of the calcium carbonate may be about 2 to 4 μm, while the particle size of the halogen calcium phosphate and aluminum oxide may be about 4 to 6 μm and 1 to 2 μm, respectively. When the light transmittance is required to be 85% to 92%, the required average thickness for the optical diffusion coating mainly having the calcium carbonate may be about 20 to about 30 μm, while the required average thickness for the optical diffusion coating mainly having the halogen calcium phosphate may be about 25 to about 35 μm, the required average thickness for the optical diffusion coating mainly having the aluminum oxide may be about 10 to about 15 μm. However, when the required light transmittance is up to 92% and even higher, the optical diffusion coating mainly having the calcium carbonate, the halogen calcium phosphate, or the aluminum oxide must be thinner.

The main material and the corresponding thickness of the optical diffusion coating can be decided according to the place for which the glass lamp tube **1** is used and the light transmittance required. It is to be noted that the higher the light transmittance of the diffusion film **13** is required, the more apparent the grainy visual of the light sources is.

In some embodiments the inner peripheral surface or the outer circumferential surface of the glass lamp tube **1** may be further covered or coated with an adhesive film (not shown) to isolate the inside from the outside of the glass lamp tube **1**. In this embodiment, the adhesive film is coated on the inner peripheral surface of the glass lamp tube **1**. The configuration of the adhesive film may be represented by the circular line indicated by the reference number **14** in FIG. **5**, which shows that the adhesive film may be formed on the inner peripheral surface of the glass lamp tube **1** and contained between the diffusion film **13** and the lamp tube **1**. The material for the coated adhesive film includes methyl vinyl silicone oil, hydro silicone oil, xylene, and calcium carbonate, wherein xylene is used as an auxiliary material. The xylene will be volatilized and removed when the coated adhesive film on the inner surface of the glass lamp tube **1** solidifies or hardens. The xylene is mainly used to adjust the capability of adhesion and therefore to control the thickness of the coated adhesive film.

In some embodiments, the thickness of the coated adhesive film may be between about 100 and about 140 micrometers (μm). The adhesive film having a thickness being less than 100 micrometers may not have sufficient shatterproof capability for the glass lamp tube **1**, and the glass lamp tube **1** is thus prone to crack or shatter. The adhesive film having a thickness being larger than 140 micrometers may reduce the light transmittance and also increases material cost. The thickness of the coated adhesive film may be between about 10 and about 800 micrometers (μm) when the shatterproof capability and the light transmittance are not strictly demanded.

In some embodiments, the LED tube lamp according to the embodiment of present invention can include an optical adhesive sheet. Various kinds of the optical adhesive sheet can be combined to constitute various embodiments of the present invention. The optical adhesive sheet, which is a clear or transparent material, is applied or coated on the surface of the LED light source **202** in order to ensure optimal light transmittance. After being applied to the LED light sources **202**, the optical adhesive sheet may have a granular, strip-like or sheet-like shape. The performance of the optical adhesive sheet depends on its refractive index and thickness. The refractive index of the optical adhesive sheet is in some embodiments between 1.22 and 1.6. In some embodiments, it is better for the optical adhesive sheet to have a refractive index being a square root of the refractive index of the housing or casing of the LED light source **202**, or the square root of the refractive index of the housing or casing of the LED light source **202** plus or minus 15%, to contribute better light transmittance. The housing/casing of the LED light sources **202** is a structure to accommodate and carry the LED dies (or chips) such as a LED lead frame. The refractive index of the optical adhesive sheet may range from 1.225 to 1.253. In some embodiments, the thickness of the optical adhesive sheet may range from 1.1 mm to 1.3 mm. The optical adhesive sheet having a thickness less than 1.1 mm may not be able to cover the LED light sources **202**, while the optical adhesive sheet having a thickness more than 1.3 mm may reduce light transmittance and increases material cost.

In process of assembling the LED light sources to the LED light strip **2**, the optical adhesive sheet is firstly applied on the LED light sources **202**; then an insulation adhesive sheet is coated on one side of the LED light strip **2**; then the LED light sources **202** are fixed or mounted on the LED light strip **2**; the other side of the LED light strip **2** being opposite to the side of mounting the LED light sources **202** is bonded and affixed to the inner surface of the lamp tube **1** by an adhesive sheet; finally, the end cap **3** is fixed to the end portion of the lamp tube **1**, and the LED light sources **202** and the power supply **5** are electrically connected by the LED light strip **2**.

In one embodiment, each of the LED light sources **202** may be provided with a LED lead frame having a recess, and an LED chip disposed in the recess. The recess may be one or more than one in amount. The recess may be filled with phosphor covering the LED chip to convert emitted light therefrom into a desired light color. Compared with a conventional LED chip being a substantial square, the LED chip in this embodiment is in some embodiments rectangular with the dimension of the length side to the width side at a ratio ranges generally from about 2:1 to about 10:1, in some embodiments from about 2.5:1 to about 5:1, and in some more desirable embodiments from 3:1 to 4.5:1. Moreover, the LED chip is in some embodiments arranged with its length direction extending along the length direction of the glass lamp tube **1** to increase the average current density of the LED chip and improve the overall illumination field shape of the glass lamp tube **1**. The glass lamp tube **1** may have a number of LED light sources **202** arranged into one or more rows, and each row of the LED light sources **202** is arranged along the length direction (Y-direction) of the glass lamp tube **1**.

Referring to FIG. **1**A, FIG. **1**B, and FIG. **1**C, an LED tube lamp in accordance with a second embodiment of the present invention includes a glass lamp tube **1**, an LED light strip **2**, and one end cap **3** disposed at one end of the glass lamp tube **1**. At least a part of the inner surface of the glass lamp tube **1** is formed with a rough surface and the roughness of the inner surface is higher than that of the outer surface. In this embodiment, the glass lamp tube **1** may have only one inlet located at one end while the other end is entirely sealed or integrally formed with tube body. The LED light strip **2** is disposed inside the glass lamp tube **1** with a plurality of LED light sources **202** mounted on the LED light strip **2**. The end cap **3** is disposed at the end of the glass lamp tube **1** where the inlet located, and the power supply **5** is provided inside the end cap **3**. In another embodiment, as shown in FIG. **1**B, the glass lamp tube **1** may have two inlets, two end caps **3** respectively disposed at two ends of the glass lamp tube **1**, and one power supply **5** provided inside one of the end caps **3**. In another embodiment, as shown in FIG. **1**C, the glass lamp tube **1** may have two inlets, two end caps **3** respectively disposed at two ends of the glass lamp tube **1**, and two power supplies **5** respectively provided inside the two end caps **3**.

The glass lamp tube **1** is covered by a heat shrink sleeve **19**. The heat shrink sleeve **19** is substantially transparent with respect to the wavelength of light from the LED light sources **202** and may be made of PFA (perfluoroalkoxy) or PTFE (poly tetra fluoro ethylene). At least a part of the inner surface of the glass lamp tube **1** is formed with a rough surface and the roughness of the inner surface is higher than that of the outer surface, such that the light from the LED light sources **202** can be uniformly spread when transmitting through the glass lamp tube **1**.

The glass lamp tube **1** and the end cap **3** are secured by a highly thermal conductive silicone gel disposed between an inner surface of the end cap **3** and outer surfaces of the glass lamp tube **1**. In some embodiments, the highly thermal conductive silicone gel has a thermal conductivity not less than 0.7 w/m·k. In some embodiments, the thermal conductivity of the highly thermal conductive silicone gel is not less than 2 w/m·k. In some embodiments, the highly thermal conducive silicone gel is of high viscosity, and the end cap **3** and the end of the glass lamp tube **1** could be secured by using the highly thermal conductive silicone gel and therefore qualified in a torque test of 1.5 to 5 newton-meters (Nt-m) and/or in a bending test of 5 to 10 newton-meters (Nt-m). The highly thermal conductive silicone gel has excellent weatherability and can prevent moisture from entering inside of the glass lamp tube **1**, which improves the durability and reliability of the LED tube lamp.

Referring to FIG. **1**A, FIG. **1**B, FIG. **1**C, and FIG. **2**, the LED light strip **2** has a bendable circuit sheet **205** mounted on the inner surface of the glass lamp tube **1**. The bendable circuit sheet **205** electrically connects the LED light sources **202** with the power supply **5**, and the length of the bendable circuit sheet **205** is larger than the length of the glass lamp tube **1**. In some embodiments, the bendable circuit sheet **205** has its ends extending beyond two ends of the glass lamp tube **1** to respectively form two freely extending end portions **21**. As shown in FIG. **2**, in which only one freely extending end portion **21** is illustrated, the freely extending end portion **21** is electrically connected to the power supply **5**. Specifically, the power supply **5** has soldering pads "a" which are capable of being soldered with the soldering pads "b" of the freely extending end portion **21** by soldering material "g".

In the previously-described first embodiment, the bendable circuit sheet **205** is made of a metal layer structure **2***a*, and the thickness of the heat shrink sleeve **19** is between 20 μm and 200 μm. However, in the second embodiment, the structure of the bendable circuit sheet **205** and the thickness of the heat shrink sleeve **19** are not limited.

In the second embodiment, the inner surface of the glass lamp tube **1** may be coated with an anti-reflection layer with a thickness of one quarter of the wavelength range of light coming from the LED light sources **202**. The configuration of the anti-reflection layer may be represented by the circular line indicated by the reference number **14** in FIG. **5**, which shows that the anti-reflection layer may be coated on the inner surface of the glass lamp tube **1**. With the anti-reflection layer, more light from the LED light sources **202** can transmit through the glass lamp tube **1**.

Referring to FIG. **4**, in the second embodiment, the glass lamp tube **1** may further include one or more reflective films **12** disposed on the inner surface of the glass lamp tube **1**. In some embodiments, only the part of the inner surface which is not covered by the reflective film **12** is formed with the rough surface. As shown in FIG. **4**, a part of light **209** from LED light sources **202** are reflected by two reflective films **12** such that the light **209** from the LED light sources **202** can be centralized to a determined direction.

Referring to FIG. **5**, in the second embodiment, the glass lamp tube **1** may further include a diffusion film **13** so that the light emitted from the plurality of LED light sources **202** is transmitted through the diffusion film **13** and the glass lamp tube **1**. The diffusion film **13** can be in form of various types as described in the first embodiment. The glass lamp tube **1** also includes a heat shrink sleeve **19** and a plurality of inner roughness **17**.

In the second embodiment, the inner peripheral surface or the outer circumferential surface of the glass lamp tube **1** may be further covered or coated with an adhesive film (not shown) to isolate the inside from the outside of the glass lamp tube **1**. The adhesive film may be coated on the inner peripheral surface of the glass lamp tube **1**.

Referring to FIG. **1**A, FIG. **1**B, and FIG. **1**C, an LED tube lamp in accordance with a third embodiment of the present invention includes a glass lamp tube **1**, an LED light strip **2** disposed inside the glass lamp tube **1**, and one end cap **3** disposed at one end of the glass lamp tube **1**. In this embodiment, as shown in FIG. **1**A, the glass lamp tube **1** may have only one inlet located at one end while the other end is entirely sealed or integrally formed with tube body. The LED light strip **2** is disposed inside the glass lamp tube **1** with a plurality of LED light sources **202** mounted on the LED light strip **2**. The end cap **3** is disposed at the end of the glass lamp tube **1** where the inlet located, and the power supply **5** is provided inside the end cap **3**. In another embodiment, as shown in FIG. **1**B, the glass lamp tube **1** may have two inlets, two end caps **3** respectively disposed at two ends of the glass lamp tube **1**, and one power supply **5** provided inside one of the end caps **3**. In another embodiment, as shown in FIG. **1**C, the glass lamp tube **1** may have two inlets, two end caps **3** respectively disposed at two ends of the glass lamp tube **1**, and two power supplies **5** respectively provided inside the two end caps **3**.

The glass lamp tube **1** is covered by a heat shrink sleeve **19**. The heat shrink sleeve **19** is substantially transparent with respect to the wavelength of light from the LED light sources **202** and may be made of PFA (perfluoroalkoxy) or PTFE (poly tetra fluoro ethylene). At least a part of the inner surface of the glass lamp tube **1** is formed with a rough surface with a roughness from 0.1 μm to 40 μm. The roughness of the inner surface is higher than that of the outer surface, such that the light from the LED light sources **202** can be uniformly spread when transmitting through the glass lamp tube **1**.

The end cap **3** is disposed at one end of the glass lamp tube **1** and the power supply **5** is provided inside the end cap **3**. The glass lamp tube **1** and the end cap **3** are secured by a highly thermal conductive silicone gel disposed between an inner surface of the end cap **3** and outer surfaces of the glass lamp tube **1**. In some embodiments, the highly thermal conductive silicone gel has a thermal conductivity not less than 0.7 w/m·k. In some embodiments, the thermal conductivity of the highly thermal conductive silicone gel is not less than 2 w/m·k. In some embodiments, the highly thermal conducive silicone gel is of high viscosity, and the end cap **3** and the end of the glass lamp tube **1** could be secured by using the highly thermal conductive silicone gel and therefore qualified in a torque test of 1.5 to 5 newton-meters (Nt-m) and/or in a bending test of 5 to 10 newton-meters (Nt-m). The highly thermal conductive silicone gel has excellent weatherability and can prevent moisture from entering inside of the glass lamp tube **1**, which improves the durability and reliability of the LED tube lamp.

Referring to FIG. **1**A, FIG. **1**B, FIG. **1**C and FIG. **2**, the LED light strip **2** has a bendable circuit sheet **205** mounted on the inner surface of the glass lamp tube **1**. The bendable circuit sheet **205** electrically connects the LED light sources **202** with the power supply **5**, and the length of the bendable circuit sheet **205** is larger than the length of the glass lamp tube **1**. The bendable circuit sheet **205** has its ends extending beyond two ends of the glass lamp tube **1** to respectively form two freely extending end portions **21**. As shown in FIG. **2**, in which only one freely extending end portion **21** is illustrated, the freely extending end portion **21** is electrically connected to the power supply **5**. Specifically, the power supply **5** has soldering pads "a" which are capable of being soldered with the soldering pads "b" of the freely extending end portion **21** by soldering material "g".

Referring to FIG. **3**, in the third embodiment, the bendable circuit sheet **205** is made of a metal layer structure **2***a*. The thickness range of the metal layer structure **2***a* may be 10 μm to 50 μm and the metal layer structure **2***a* may be a patterned wiring layer.

In the third embodiment, the inner surface of the glass lamp tube **1** is coated with an anti-reflection layer with a thickness of one quarter of the wavelength range of light coming from the LED light sources **202**. With the anti-reflection layer, more light from the LED light sources **202** can transmit through the glass lamp tube **1**.

Referring to FIG. **4**, in the third embodiment, the glass lamp tube **1** may further include one or more reflective films **12** disposed on the inner surface of the glass lamp tube **1**. In some embodiments, only the part of the inner surface which is not covered by the reflective film **12** is formed with the rough surface. As shown in FIG. **4**, a part of light **209** from LED light sources **202** are reflected by two reflective films **12** such that the light **209** from the LED light sources **202** can be centralized to a determined direction.

Referring to FIG. **5**, in the third embodiment, the glass lamp tube **1** may further include a diffusion film **13** so that the light emitted from the plurality of LED light sources **202** is transmitted through the diffusion film **13** and the glass lamp tube **1**. The diffusion film **13** can be in form of various types as described in the first embodiment. The glass lamp tube **1** also includes a heat shrink sleeve **19** and a plurality of inner roughness **17**. As shown in FIG. **5**, the reflective film **12** further comprises an opening (where the reflective film **12** is divided into a left part and a right part in a cross-sectional view shown in FIG. **5**). The LED light strip **2** is disposed in the opening. The diffusion film **13** covers the opening of the reflective film **12**.

In the third embodiment, the inner peripheral surface or the outer circumferential surface of the glass lamp tube **1** may be further covered or coated with an adhesive film (not shown) to isolate the inside from the outside of the glass lamp tube **1**. The adhesive film may be coated on the inner peripheral surface of the glass lamp tube **1**.

An embodiment of the invention provides an LED tube lamp, referring to FIG. **6** to FIG. **10**, which comprises a housing **1**, an LED light strip **2**, a light strip insulation gel **7**, a light source gel **8**, end caps **3**, a hot melt adhesive **6**, an LED power **5**, and an adhesive **4**. The LED light strip **2** is fixed on an internal wall of the housing **1** by the adhesive **4**. The LED light strip **2** is provided with a female plug **201** and comprises LED light sources **202**. The end cap **3** is provided with hollow conductive pins **301**. An end of the LED power **5** is provided with a male plug **501**, and another end is provided with a metal pin **502**. The male plug **501** on the end of the LED power **5** is plugged into the female plug **201** of the LED light strip **2**. The metal pin **502** on the other end is plugged into the hollow conductive pin **301**. As such, an electrical connection is performed. The light strip insulation gel **7** is applied on the LED light strip **2**. The light source gel **8** is applied on the surface of the LED light source **202**. As such, the entire LED light strip **2** is insulated. Incident of electrical shock can be avoided even the housing **1** is partially broken. The end cap **3** is fixed on ends of the housing by the hot melt adhesive **6**. As such, an LED tube lamp is assembled.

The LED light strip **2** is fixed on an internal wall of the housing **1** by the adhesive **4**. As shown in FIG. **7**, the adhesive **4** shown in the figure is divided into three sections. It is noted that the number or the shape of the adhesive **4** is not limited. The adhesive **4** may be silicone gel or silicone gel sheet of a strip shape.

The LED light strip **2** is provided with the female plug **201**. The end cap **3** is provided with hollow conductive pins **301**. The metal pin **502** on the LED power **5** is plugged into the hollow conductive pin **301** on the end cap **3**. The male plug **501** is plugged into the female plug **201** of the LED light strip **2** to be electrical connection. Current passing through the hollow conductive pin **301** of the end cap **3** is transmitted to the metal pin **502** of the power **5**. After being transformed by the power **5**, the current is outputted by the male plug **501** and is transmitted to the LED light strip **2** through the female plug **201** of the LED light strip **2**. As such, the LED light sources **202** on the LED light strip **2** can be turned on. The fabrication is simple, which is benefit to be automatic.

In addition, please refer to the cross sectional schematic view of the housing of FIG. **8**. Taking the standard specification for T8 lamp as an example, **101** is the portion in the rear of the shrunk opening. The outer diameter is between 20.9 mm to 23 mm. If the outer diameter being less than 20.9 mm would be too small to fittingly insert the power components into the housing **1**. **102** is the portion in the front of the shrunk opening. The outer diameter is between 25 mm to 28 mm. If the outer diameter being less than 25 mm would be inconvenient to have the opening be shrunk. If the outer diameter is greater than 28 mm, it is not compliant to the industrial standard. **103** is the transition portion from the front of the shrunk opening to the rear of the shrunk opening, which is of an arc shape. Wherein, the length of the transition portion is 1-4 mm. If the length is less than 1 mm, the strength of the shrunk opening is not sufficient. If the length is greater than 4 mm, the length of the end cap **3** would be increased, light emitting surface would be decreased, and material would be waste. Based upon T8 structure and analogously other specifications of T5, T9, or T12 . . . and the like and considering the relation of the thickness of the end cap and the thickness of the hot melt adhesive, the difference of the outer diameters of the main region of the glass tube and the end portion of the shrunk opening should be 2-7 mm or even 1-10 mm. It is noted that the two ends of the housing in the figure are shrunk. But it is not limited to two ends to be shrunk. A case that one end is shrunk and the other end is not shrunk is also included in the claimed scope of the invention (the shrunk opening may be on the end with the power or on the end without the power).

In addition, please refer to the three dimensional schematic view of the end cap of FIG. **9**. The material of the end cap **3** shown in the figure includes partial plastic and partial metal. Wherein, **302** is the plastic portion, and **3021** is the extending plastic portion. The outer diameter of the plastic portion **302** is 0.15-0.30 mm greater than that of the extending plastic portion **3021**. **303** is the metal portion (e.g., aluminum alloy). The proportion of the plastic portion **302** and the metal portion **303** is 2.5:1 to 5:1. In addition, the hollow conductive pin **301** is installed inside the plastic portion **302**. An end portion of the housing **1** is inserted to the end cap **3**. The position to which the housing **1** is inserted is between ⅓ and ⅔ of the metal portion **303**. The advantage is that it won't form a short circuit while the hollow conductive pin is electrified. A creepage distance is increased by the plastic portion. While the end cap is entire aluminum, a bottom portion of the hollow conductive pin **301** needs to be insulated to bear high voltage since the electric current would pass through the hollow conductive pin **301**. In the present case, the material of the portion **302** is plastic, which increases a distance between the hollow conductive pin and the metal portion **303** and thus can pass a high voltage test. The end cap **3** is fixed to the end of the housing **1** via the metal portion **303** by the hot melt adhesive **6**. By external solidifying equipment, heat can be transferred to it and further transferred to the hot melt adhesive **6** to solidify it and fix the housing **1** and the end cap **3**. It is noted that the material of the end cap **3** shown in FIG. **9** including partial plastic and partial metal. In practice, the material may be entire plastic or entire metal. The manner for fixation of the plastic end cap and the housing **1** and be referred to FIGS. **11**-**12**. The steps of the hot melt adhesive **6** being solidified to be connected with the plastic end cap and the housing **1** include: the first step, wherein a magnetic metal member **9** is disposed inside the plastic end cap **10**, and the magnetic metal member **9** is placed on a step of the plastic end cap **10**; the second step, wherein an inner side of the magnetic metal member **9** is applied with the hot melt adhesive; the third step, wherein the hot melt adhesive **6** is adhered to a peripheral surface around the shrunk opening of the housing **1** of the shrunk glass tube; and the fourth step, wherein the T-LED tube processed with the above steps is disposed in an induction coil **11**, such that the magnetic metal member **9** in the plastic end cap **10** and the induction coil **11** are disposed opposite, and the center of the plastic end cap **10** overlaps the center of the induction coil **11** as possible, in which the error is no more than 0.05 mm. Alternatively, by another technique, microwave is controlled to be concentrated closing the magnetic metal member without affection to electric components. The yield rate can be significantly increased. After the above steps are processed, the relation of each component can be referred to FIG. **12**. It is noted, the hot melt adhesive **6** is distributed on two sides of the housing **1** of the shrunk glass tube in FIG. **12**, and this is a state after the end cap is inserted in the housing **1** of the glass tube. During the insertion of the end cap into the housing **1** of the glass tube, the hot melt adhesive **6** is capable of flowing, and a part of it would be squeezed out of the housing **1** of the glass tube to the other side thereof. The original thickness of the hot melt adhesive is 0.2-0.5 mm. After solidifying, it expands. The manner for fixation of the metal end cap and the housing **1** is the hot melt adhesive **6** being solidified to be connected with the metal end cap and the housing **1** in a conventional thermal conduction manner. It is no need to go into details.

In addition, please refer to FIG. **14**, which illustrates the relation of end cap **3** and the housing **1**. The housing **1** inserted in the end cap **3** is shown in FIG. **14**. Observing along A direction of the cross sectional view, the components from the outside to the inside in sequence are the metal portion **303** of the end cap **3**, the extending plastic portion **3021**, the hot melt adhesive **6**, and the housing **1**. Observing along B direction of the cross sectional view, the components from the outside to the inside in sequence are the metal portion **303** of the end cap **3**, the hot melt adhesive **6**, and the housing **1**.

Please refer to FIG. **13**. While the LED housing **1** is a shrunk glass tube and the LED power **19** is not a module, i.e., components and circuit board of the power **11** are exposed, it is suitable that the LED light strip **2** is a flexible substrate, and, preferably, the electrical connection of the flexible substrate and the power **11** is to have the flexible substrate pass through the shrunk opening of the glass tube to be connected to an output end of the power. The output end is provided with soldering pads with an amount of tin solder to increase the thickness. The LED light strip **2** also has soldering pads, which are soldered to the soldering pads of an output end of the LED light strip. The advantage is that there is no need of wiring connection, such that the quality of product is stable. As such, the LED light strip **2** has no need of the female plug **201**. The flexible substrate has three layers. The upper and lower layers are metal layers. The middle layer is dielectric layer. In such case, it is simplified that only two layers are required. One layer is metal layer for power, and the other layer is dielectric layer. The original metal layer adhered to the bottom of the glass tube can be omitted to form a two-layer structure. A thermal conduction interface is omitted. Moreover, there can be only one power layer. Only wires (copper) are printed thereon. Two thermal conduction interfaces are omitted. The efficiency of LED light source is increased.

Referring to FIG. **15**, in one embodiment, the light strip is a hard circuit board **22** made of aluminum, such that the ends thereof can be mounted at ends of the lamp tube **1**, and the power supply **5** is soldering bonded to the ends or terminals of the aluminum circuit board **22** in a manner that the printed circuit board of the power supply **5** is perpendicular to the hard circuit board **22**. The soldering bonding technique is more convenient to accomplish. In addition, the length of the end cap **3** can be reduced some there is no need of space in the longitudinal direction for the power supply **5**. The effective illuminating areas of the LED tube lamp could also increase. Moreover, in the above embodiments, the power supply **5** is not only installed with power supply components but also soldered with other metal wires between the power supply **5** and the hollow conductive pin **301**. In the embodiment, a conductive lead **53** could be formed directly on the power supply **5** as a power supply component, which can be used for electrical connection with the end cap **3** without soldering other metal wires. It facilitates and simplifies the manufacturing process.

Referring to FIG. **16**, in one embodiment, the LED light strip **2** includes a bendable circuit sheet having in sequence a first wiring layer **2***a*, a dielectric layer **2***b*, and a second wiring layer **2***c*. The thickness of the second wiring layer **2***c* is greater than that of the first wiring layer **2***a*, and the length of the LED light strip **2** is greater than that of the lamp tube **1**. The end region of the light strip **2** extending beyond the end portion of the lamp tube **1** without disposition of the light source **202** is formed with two separate through holes **203** and **204** to respectively electrically communicate the first wiring layer **2***a* and the second wiring layer **2***c*. The through holes **203** and **204** are not communicated to each other to avoid short.

When the bendable circuit sheet of the LED light strip **2** includes in sequence the first wiring layer **2***a*, the dielectric layer **2***b*, and the second wiring layer **2***c* as shown in FIG. **16**, a freely extending end portions **21** of the LED light strip **2** can be used to accomplish the connection between the first wiring layer **2***a* and the second wiring layer **2***c* and arrange the circuit layout of the power supply **5**.

The above-mentioned features of the present invention can be accomplished in any combination to improve the LED tube lamp, and the above embodiments are described by way of example only. The present invention is not herein limited, and many variations are possible without departing from the spirit of the present invention and the scope as defined in the appended claims.

What is claimed is:

1. An LED tube lamp, comprising:

a tube, comprising:

a main body; and

two rear end regions respectively at two ends of the main body, wherein an outer diameter of each of the rear end regions is less than that of the main body;

two end caps respectively sleeving the two rear end regions, each of the end caps comprising:

a metal ring member substantially coaxial with the tube, the metal ring member sleeving the respective rear end region;

an insulating end wall substantially perpendicular to the axial direction of the tube; and

two pins on the insulating end wall for receiving an external driving signal;

an LED light strip disposed on an inner circumferential surface of the main body with a plurality of LED light sources mounted thereon;

a power supply disposed at one end or two ends of the tube and configured to drive the plurality of LED light sources; and

an adhesive disposed between each of the metal ring members and each of the rear end regions;

wherein a rough layer is formed on the inner circumferential surface of the main body and the roughness of the rough layer is higher than that of the outer surface of the main body, so that the light emitted from the LED light sources passing through the rough layer and then through the main body.

2. The LED tube lamp of claim 1, wherein the LED light strip further comprises a mounting region and a connecting region, the plurality of LED light sources are mounted on the mounting region, the connecting region electrically connecting the plurality of LED light sources to the power supply.

3. The LED tube lamp of claim 2, wherein the mounting region is attached on the inner circumferential surface of the main body and the connecting region is detached from the inner surface of the tube to form a freely extending end portion.

4. The LED tube lamp of claim 3, wherein a portion of the freely extending end portion of the LED light strip is in the tube and another portion of the freely extending end portion of the LED light strip is extending beyond an end of the tube and into the end cap.

5. The LED tube lamp of claim 4, wherein the power supply comprises a circuit board, the circuit board being disposed in the end cap, the freely extending end portion of the LED light strip being directly soldered to the circuit board of the power supply.

6. The LED tube lamp of claim 2, wherein the power supply comprises a plurality of electronic components mounted on the connecting region.

7. The LED tube lamp of claim 6, wherein the LED light strip comprises a first wiring layer, a dielectric layer and a second wiring layer, the dielectric layer is disposed between the first wiring layer and the second wiring layer, the plurality of LED light sources are mounted on the first wiring layer.

8. The LED tube lamp of claim 7, wherein the second wiring layer is a piece of metal material and a thickness of the second wiring layer is great than the first wiring layer.

9. The LED tube lamp of claim 8, wherein the LED light strip further comprises a protective layer disposed on the first wiring layer.

10. The LED tube lamp of claim 1, wherein the LED tube lamp further comprises a diffusion film covering the outer surface of the main body, so that the light emitted from the LED light sources passing through the rough layer and then through the diffusion film.

11. The LED tube lamp of claim 10, wherein the LED tube lamp further comprises an adhesive film contained in-between the tube of glass and the diffusion film.

12. The LED tube lamp of claim 10, wherein the tube is a glass tube and the LED tube lamp further comprises an anti-reflection layer coated on the inner surface of the tube which is capable of reducing a reflection occurring at an interface between the glass lamp tube's inner surface and air and allowing more light from the LED light sources transmitting through the glass lamp tube; and wherein the light output from the LED light sources transmits through the anti-reflection layer, the rough layer, the diffusion film, and the tube.

13. An LED tube lamp, comprising:

a tube, comprising:

a main body; and

two rear end regions respectively at two ends of the main body;

two end caps respectively sleeving the two rear end regions, each of the end caps comprising:

a lateral wall substantially coaxial with the tube, the lateral wall sleeving the respective rear end region;

an end wall substantially perpendicular to the axial direction of the tube; and

two pins on the end wall for receiving an external driving signal;

an LED light strip disposed on an inner circumferential surface of the main body with a plurality of LED light sources mounted thereon;

a power supply comprising a circuit board and configured to drive the plurality of LED light sources, the circuit board disposed inside one of the rear end regions and one of the end caps;

an adhesive disposed between each of the lateral wall and each of the rear end regions; and

a diffusion film disposed on the glass lamp tube so that light emitted from the LED light sources passing through the inner surface of the glass lamp tube and then passing through the diffusion film on the glass lamp tube.

14. The LED tube lamp of claim 13, wherein a portion of the circuit board, one of the rear end regions, the adhesive and one of the lateral wall are stacked sequentially in a radial direction of the LED tube lamp.

15. The LED tube lamp of claim 14, wherein an outer diameter of each of the rear end regions is less than the outer diameter of the main body.

16. The LED tube lamp of claim 14, wherein the LED light strip further comprises a mounting region and a connecting region, the plurality of LED light sources are mounted on the mounting region, the connecting region electrically connecting the plurality of LED light sources to the power supply.

17. The LED tube lamp of claim 16, wherein the mounting region is attached on the inner circumferential surface of the main body and the connecting region is detached from the inner surface of the tube to form a freely extending end portion.

18. The LED tube lamp of claim 17, wherein the freely extending end portion of the LED light strip is directly soldered to the circuit board of the power supply.

19. The LED tube lamp of claim **14**, wherein the LED light strip comprises a first wiring layer, a dielectric layer and a second wiring layer, the dielectric layer is disposed between the first wiring layer and the second wiring layer, and the plurality of LED light sources are mounted on the first wiring layer.

20. The LED tube lamp of claim **19**, wherein the second wiring layer is a piece of metal material and the thickness of the second wiring layer is great than the first wiring layer.

21. The LED tube lamp of claim **20**, wherein the LED light strip further comprises a protective layer disposed on the first wiring layer.

22. The LED tube lamp of claim **14**, wherein the LED tube lamp further comprises an adhesive film contained in-between the glass lamp tube and the diffusion film.

23. The LED tube lamp of claim **14**, wherein the LED tube lamp further comprises an anti-reflection layer coated on the inner surface of the tube.

* * * * *

09/16/2021	178	Redacted Public Version *Defendants' Response to Plaintiffs' Motions in Liimine (Nos. 1−19)* of 168 Sealed Document, by CH Lighting Technology Co., Ltd., Elliott Electric Supply, Inc., Shaoxing Ruising Lighting Co., Ltd.. (Hill, Robert) (Entered: 09/16/2021)
09/16/2021	179	Redacted Copy *Plaintiffs' Jiaxing Super Lighting Electric Appliance Co.'s and Obert Inc.'s Opposition to Defendants' Motions in Limine (Nos. 1−8)* of 170 Sealed Document,, by Jiaxing Super Lighting Electric Appliance, Co., Ltd., Obert, Inc.. (Bernstein, Matthew) (Entered: 09/16/2021)
09/20/2021	180	Sealed Document: Defendants' Opposition to Plaintiff's Motion for Sanctions of 176 Sealed Document, by CH Lighting Technology Co., Ltd., Elliott Electric Supply, Inc., Shaoxing Ruising Lighting Co., Ltd. (Attachments: # 1 Memo in Support Declaration of R Hill) (Hill, Robert) (Entered: 09/20/2021)
09/20/2021	181	NOTICE *Pursuant to 35 U.S.C. § 282* by CH Lighting Technology Co., Ltd., Elliott Electric Supply, Inc., Shaoxing Ruising Lighting Co., Ltd. (Hill, Robert) (Entered: 09/20/2021)
09/21/2021	182	ORDER, (Pretrial Conference RESET for 10/6/2021 01:30 PM before Judge Alan D Albright). Signed by Judge Alan D Albright. (bot1) (Entered: 09/21/2021)
09/21/2021	183	ORDER, (Jury Selection RESET for 10/29/2021 09:30AM before Judge Alan D Albright). Signed by Judge Alan D Albright. (bot2) (Entered: 09/21/2021)
09/21/2021	184	ORDER, (Jury Trial RESET for 11/1/2021 09:30 AM before Judge Alan D Albright). Signed by Judge Alan D Albright. (bot1) (Entered: 09/21/2021)
09/27/2021	185	Sealed Document: Plaintiffs Jiaxing Super Lighting Electric Appliance Co., Ltd., and Obert, Inc.'s Reply In Support of Motion for Sanctions of 176 Sealed Document, by Jiaxing Super Lighting Electric Appliance, Co., Ltd., Obert, Inc. (Bernstein, Matthew) (Entered: 09/27/2021)
09/28/2021	186	ADVISORY TO THE COURT by Jiaxing Super Lighting Electric Appliance, Co., Ltd., Obert, Inc. . (Attachments: # 1 Defendants Proposed Juror Questionnaire, # 2 Joint Proposed Voir Dire Questions, # 3 Plaintiffs Juror Questionnaire)(Bernstein, Matthew) (Entered: 09/28/2021)
09/29/2021		Text Order GRANTING 51 Motion for Leave to File Excess Pages entered by Judge Alan D Albright. (This is a text−only entry generated by the court. There is no document associated with this entry.) (RRlc) (Entered: 09/29/2021)
09/29/2021		Text Order GRANTING 56 Motion for Leave to File Sealed Document entered by Judge Alan D Albright. (This is a text−only entry generated by the court. There is no document associated with this entry.) (RRlc) (Entered: 09/29/2021)
09/30/2021	187	NOTICE of Attorney Appearance by David C. Schulte on behalf of CH Lighting Technology Co., Ltd., Elliott Electric Supply, Inc., Shaoxing Ruising Lighting Co., Ltd. . Attorney David C. Schulte added to party CH Lighting Technology Co., Ltd.(pty:dft), Attorney David C. Schulte added to party Elliott Electric Supply, Inc.(pty:dft), Attorney David C. Schulte added to party Shaoxing Ruising Lighting Co., Ltd. (pty:dft) (Schulte, David) (Entered: 09/30/2021)
09/30/2021	188	ADVISORY TO THE COURT by Jiaxing Super Lighting Electric Appliance, Co., Ltd., Obert, Inc. . (Attachments: # 1 Joint Proposed Preliminary Jury Instructions, # 2 Proposed Final Jury Instructions, # 3 Proposed Verdict Forms)(Bernstein, Matthew) (Entered: 09/30/2021)
10/05/2021	189	ORDER, (Pretrial Conference RESET for 10/6/2021 03:00 PM before Judge Alan D Albright). Signed by Judge Alan D Albright. (bot1) (Entered: 10/05/2021)
* 10/06/2021	190	Minute Entry for proceedings held Via Zoom before Judge Alan D Albright: Pretrial Conference held on 10/6/2021. Case called for final pretrial conference by zoom. The parties have reached an agreement on thePlaintiff's motion in limine #9. The Court will grant Plaintiff's Motion in Limine # 2, 10, 14, 15, 17, and 19.The Court will grant the Defendant's Motion in Limine #1, 3 and 5 and will deny the Defendant's Motion inLimine #4, 7 and 8, The Court denied the Defendant's Daubert to Exclude Certain Opinions and Testimony of Lauren Kindler. The Court reviews his normal voir dire and jury trial procedures. There are 3 patents in this case. The Court will allow 8 hours

* Identifies a text-only order on appeal.

		per side. If parties are being efficient and need more time the Court will consider that. Opening and closing arguments are 30 minutes maximum. The Judge suggests that the parties have a translator in the courtroom in order to facilitate the remote witnesses. (Minute entry documents are not available electronically.) (Court Reporter Shelly Holmes.)(jc5) (Entered: 10/07/2021)
10/08/2021	191	Transcript filed of Proceedings held on 10/6/21, Proceedings Transcribed: Pretrial Hearing. Court Reporter/Transcriber: Shelly Holmes, CSR, TCRR, Telephone number: (903) 720−6009 (shellyholmes@hotmail.com). Parties are notified of their duty to review the transcript to ensure compliance with the FRCP 5.2(a)/FRCrP 49.1(a). A copy may be purchased from the court reporter or viewed at the clerk's office public terminal. If redaction is necessary, a Notice of Redaction Request must be filed within 21 days. If no such Notice is filed, the transcript will be made available via PACER without redaction after 90 calendar days. The clerk will mail a copy of this notice to parties not electronically noticed Redaction Request due 10/29/2021, Redacted Transcript Deadline set for 11/8/2021, Release of Transcript Restriction set for 1/6/2022, (kd) (Entered: 10/08/2021)
10/08/2021	192	Standing Order Regarding Order Governing Proceedings Patent Cases. Signed by Judge Alan D Albright. (Entered: 10/13/2021)
10/13/2021	193	MOTION to Appear Pro Hac Vice by Sara Schretenthaler Staha *for William E. Sterling* (Filing fee $ 100 receipt number 0542−15329935) by on behalf of CH Lighting Technology Co., Ltd., Elliott Electric Supply, Inc., Shaoxing Ruising Lighting Co., Ltd.. (Attachments: # 1 Proposed Order)(Staha, Sara) (Entered: 10/13/2021)
10/15/2021	194	ORDER GRANTING 193 Motion to Appear Pro Hac Vice for Attorney William E. Sterling. Attorney added for CH Lighting Technology Co., Ltd., Elliott Electric Supply, Inc., Shaoxing Ruising Lighting Co., Ltd. Pursuant to our Administrative Policies and Procedures for Electronic Filing, the attorney hereby granted to practice pro hac vice in this case must register for electronic filing with our court within 10 days of this order, **if he/she has not previously done so for a prior case in this District**. Signed by Judge Alan D Albright. (jkda) (Entered: 10/15/2021)
10/15/2021	195	Sealed Order. Signed by Judge Alan D Albright. (jc5) (Entered: 10/15/2021)
10/15/2021	196	ORDER CONCERNING FINAL PRETRIAL CONFERENCE MOTIONS (Redacted)− re 195 Sealed Order. Signed by Judge Alan D Albright. (jc5) (Entered: 10/18/2021)
10/19/2021	197	ORDER SETTING VOIR DIRE AND PRE−VOIR DIRE CONFERENCE, Video Conference (to discuss voir Dire protocol Hearing set for 10/28/2021 01:30 PM before Judge Jeffrey C. Manske. Voir Dire is set for 10/29/2021 09:30AM before Judge Jeffrey C. Manske in District Courtroom #1. Signed by Judge Jeffrey C. Manske. (jc5) (Entered: 10/19/2021)
10/20/2021	198	Sealed Motion to Exclude Never Before Disclosed Witness Eric Marsh by Jiaxing Super Lighting Electric Appliance, Co., Ltd., Obert, Inc. (Attachments: # 1 Exhibit D to Bernstein Declaration) (Bernstein, Matthew) (Entered: 10/20/2021)
10/20/2021	199	MOTION to Exclude *Declaration of Matthew Bernstein ISO of Plaintiffs' Emergency Motion to Exclude Never Before Disclosed Witness Eric Marsh* by Jiaxing Super Lighting Electric Appliance, Co., Ltd., Obert, Inc.. (Attachments: # 1 Exhibit 1, # 2 Exhibit 2, # 3 Exhibit 3, # 4 Exhibit 4, # 5 Exhibit 5, # 6 Exhibit 6, # 7 Exhibit 7, # 8 Exhibit 8, # 9 Exhibit 10, # 10 Exhibit 11, # 11 Exhibit 12, # 12 Exhibit 13, # 13 Exhibit 14)(Bernstein, Matthew) (Entered: 10/20/2021)
10/21/2021	200	NOTICE of Attorney Appearance by Natalie Cooley Parker on behalf of CH Lighting Technology Co., Ltd., Elliott Electric Supply, Inc., Shaoxing Ruising Lighting Co., Ltd. (Parker, Natalie) (Entered: 10/21/2021)
10/22/2021	201	Sealed Document: *Defendants' Opposition to Plaintiffs' Motion* of 198 Sealed Motion to Exclude Never Before Disclosed Witness Eric Marsh by Jiaxing Super Lighting Electric Appliance, Co., Ltd., Obert, Inc. by CH Lighting Technology Co., Ltd., Elliott Electric Supply, Inc., Shaoxing Ruising Lighting Co., Ltd. (Attachments: # 1 Exhibit Ex A to Declaration of Hill) (Hill, Robert) (Entered: 10/22/2021)

	10/22/2021	202	AFFIDAVIT in Support of 201 Sealed Document, *Declaration of Robert S. Hill Filed in Support of Defendants' Opposition to Plaintiffs' Emergency Motion* by CH Lighting Technology Co., Ltd., Elliott Electric Supply, Inc., Shaoxing Ruising Lighting Co., Ltd.. (Attachments: # 1 Exhibit Ex B to Declaration of Hill, # 2 Exhibit Ex C to Declaration of Hill)(Hill, Robert) (Entered: 10/22/2021)
	10/24/2021	203	Sealed Document: Plaintiffs Jiaxing Super Lighting Electric Appliance Co., ld., and Obert, Inc.'s Reply in Support of Emergency Motion to Exclude Never Before Disclosed Witness Eric Marsh of 198 Sealed Motion to Exclude Never Before Disclosed Witness Eric Marsh by Jiaxing Super Lighting Electric Appliance, Co., Ltd., Obert, Inc. by Jiaxing Super Lighting Electric Appliance, Co., Ltd., Obert, Inc. (Bernstein, Matthew) (Entered: 10/24/2021)
	10/26/2021	204	ORDER, (Discovery Hearing set for 10/26/2021 02:00 PM before Judge Alan D Albright). Signed by Judge Alan D Albright. (bot1) (Entered: 10/26/2021)
	10/26/2021	205	Minute Entry for proceedings held before Judge Alan D Albright: Discovery Hearing held on 10/26/2021 (Minute entry documents are not available electronically.) Case called for Discovery Hearing by Zoom. The parties discussed the possible testimony of a latelyadded witness. The Court heard argument and will make a ruling in Order. (Court Reporter Shelly Holmes.)(jc5) (Entered: 10/26/2021)
*	10/27/2021		Text Order GRANTING 198 Sealed Motion entered by Judge Alan D Albright. Defendants conceded on October 27, 2021, that they failed to provide notice to Plaintiffs during discovery that Mr. Umesh Baheti would be authenticating MaxLite documents. The Court therefore ORDERS that Eric Marsh, Mr. Baheti's belatedly identified replacement, is excluded as a witness. (This is a text−only entry generated by the court. There is no document associated with this entry.) (RRlc) (Entered: 10/27/2021)
	10/27/2021	206	JURY SEQUESTRATION ORDER. Signed by Judge Alan D Albright. (jc5) (Entered: 10/27/2021)
	10/27/2021	207	Sealed Document filed: PRELIMINARY JURY INSTRUCTIONS. (jc5) (Entered: 10/27/2021)
	10/27/2021	208	MOTION to Appear Pro Hac Vice by Sara Schretenthaler Staha *for Zoe Phelps* (Filing fee $ 100 receipt number 0542−15380635) by on behalf of CH Lighting Technology Co., Ltd., Elliott Electric Supply, Inc., Shaoxing Ruising Lighting Co., Ltd.. (Attachments: # 1 Proposed Order)(Staha, Sara) (Entered: 10/27/2021)
	10/28/2021	209	NOTICE OF TRIAL PROCEDURES. (jc5) (Entered: 10/28/2021)
	10/28/2021	210	Transcript filed of Proceedings held on 10/26/21, Proceedings Transcribed: Discovery Hearing. Court Reporter/Transcriber: Shelly Holmes, CSR, TCRR, Telephone number: (903) 720−6009 (shellyholmes@hotmail.com). Parties are notified of their duty to review the transcript to ensure compliance with the FRCP 5.2(a)/FRCrP 49.1(a). A copy may be purchased from the court reporter or viewed at the clerk's office public terminal. If redaction is necessary, a Notice of Redaction Request must be filed within 21 days. If no such Notice is filed, the transcript will be made available via PACER without redaction after 90 calendar days. The clerk will mail a copy of this notice to parties not electronically noticed Redaction Request due 11/18/2021, Redacted Transcript Deadline set for 11/29/2021, Release of Transcript Restriction set for 1/26/2022, (kd) (Entered: 10/28/2021)
	10/28/2021	211	Minute Entry for proceedings held before Judge Jeffrey C. Manske: Pre−Voir Dire Conference held on 10/28/2021. CASE CALLED FOR PRE−VOIR DIRE CONFERENCE. APPEARANCES MADE. COURT ANDCOUNSEL DISCUSS VOIR DIRE PROCEDURES. COUNSEL TO ARRIVE TOMORROW AT 8:45AM. (Minute entry documents are not available electronically.) (Court Reporter FTR.)(jc5) (Entered: 10/28/2021)
	10/29/2021	212	ORDER GRANTING 208 Motion to Appear Pro Hac Vice for Attorney Zoe Phelps. Attorney added for CH Lighting Technology Co., Ltd., Elliott Electric Supply, Inc., Shaoxing Ruising Lighting Co., Ltd. Pursuant to our Administrative Policies and Procedures for Electronic Filing, the attorney hereby granted to practice pro hac vice in this case must register for electronic filing with our court within 10 days of this order, **if he/she has not previously done so for a prior case in this District**. Signed

* Identifies a text-only order on appeal.

			by Judge Alan D Albright. (jkda) (Entered: 10/29/2021)
	10/29/2021	213	Transcript filed of Proceedings held on 10−29−21, Proceedings Transcribed: Voir Dire. Court Reporter/Transcriber: Kristie Davis, Telephone number: 254−340−6114, Email: kristie_davis@txwd.uscourts.gov. (kd) (Entered: 10/29/2021)
	10/29/2021	214	NOTICE of Attorney Appearance by Morgan J. Kleoppel on behalf of CH Lighting Technology Co., Ltd., Elliott Electric Supply, Inc., Shaoxing Ruising Lighting Co., Ltd. . Attorney Morgan J. Kleoppel added to party CH Lighting Technology Co., Ltd.(pty:dft), Attorney Morgan J. Kleoppel added to party Elliott Electric Supply, Inc.(pty:dft), Attorney Morgan J. Kleoppel added to party Shaoxing Ruising Lighting Co., Ltd. (pty:dft) (Kleoppel, Morgan) (Entered: 10/29/2021)
	10/29/2021	215	Minute Entry for proceedings held before Judge Jeffrey C. Manske: Jury Selection held on 10/29/2021. PARTIES ANNOUNCE READY. VOIR DIRE BEGINS. JURY SELECTION HELD. JURORS SWORN. JURY TRIAL BEGINS 11/1/2021 @ 9:00 AM. (Minute entry documents are not available electronically). (Court Reporter Kristie Davis.)(jc5) (Entered: 11/01/2021)
	11/01/2021	216	Minute Entry for proceedings held before Judge Alan D Albright: Pretrial Conference held on 11/1/2021. Case called for pretrial hearing outside the presence of the Jury − parties discussed exhibits and theCourt explained his procedure for having exhibits admitted. Parties discussed that the first 2 witnesses for plaintiff will be by zoom from Macao. (Minute entry documents are not available electronically.) (Court Reporter Shelly Holmes.)(jc5) (Entered: 11/01/2021)
	11/01/2021	217	Minute Entry for proceedings held before Judge Alan D Albright: Jury Trial begun on 11/1/2021 (Minute entry documents are not available electronically.) (Jury Trial set for 11/2/2021 08:30 AM before Judge Alan D Albright,). (Court Reporter Shelly Holmes.)(jc5) (Entered: 11/03/2021)
	11/02/2021	218	Minute Entry for proceedings held before Judge Alan D Albright: Hearing Out of Jury Presence held on 11/2/2021 (Minute entry documents are not available electronically.) (Court Reporter Shelly Holmes.) (jc5) (Entered: 11/03/2021)
	11/02/2021	219	Minute Entry for proceedings held before Judge Alan D Albright: Jury Trial held on 11/2/2021. EVIDENCE PRESENTED ON BEHALF OF PLA/DEFT. PLAINTIFF REST− 10:25. DEF MOTION (ORAL) FOR JUDGMENT AS A MATTER OF LAW REGARDING. Jury Trial set to continue 11/3/2021 01:00 PM before Judge Alan D Albright. (Minute entry documents are not available electronically.) (Court Reporter Shelly Holmes.) (jc5) (Entered: 11/03/2021)
	11/03/2021	220	Minute Entry for proceedings held before Judge Alan D Albright: Hearing Out of Jury Presence held on 11/3/2021 (Minute entry documents are not available electronically.) (Court Reporter Shelly Holmes.) (jc5) (Entered: 11/03/2021)
*	11/03/2021	221	Minute Entry for proceedings held before Judge Alan D Albright: Jury Trial held on 11/3/2021. PLAINTIFF REST− 4:28 (rebuttal). DEFENDANT REST− 3:40. DEFENDANT'S MOTION (ORAL) FOR JUDGMENT AS A MATTER OF LAW (DENIED). PLAINTIFF'S MOTION (ORAL) FOR JUDGMENT AS A MATTER OF LAW AS TO INVALIDITY ON ALL 3 GROUNDS OF 125 PATENT AND ONE OF TWO GROUNDS OF 541 PATENT IN OPEN COURT (GRANTED). COURT CHARGES JURY. (Jury Trial set for 11/4/2021 08:30 AM before Judge Alan D Albright,). (Minute entry documents are not available electronically.) (Court Reporter Shelly Holmes.)(jc5) (Entered: 11/04/2021)
	11/04/2021	222	Minute Entry for proceedings held before Judge Alan D Albright: Hearing Out of Jury Presence held on 11/4/2021 (Minute entry documents are not available electronically.) (Court Reporter Shelly Holmes.) (jc5) (Entered: 11/04/2021)
	11/04/2021	223	Minute Entry for proceedings held before Judge Alan D Albright: Jury Trial completed on 11/4/2021. JURY NOTES #1, 2 and 3 TENDERED TO THE COURT(Jurors marked Jury Note #2 as #1 and #3 as #2). CLOSING ARGUMENTS OF COUNSEL FOR PLA/DEFT. JURY RETIRES TO DELIBERATE. JURY POLLED/DISCHARGED. TRIAL CONCLUDED. (Minute entry documents are not available electronically.) (Court Reporter Shelly Holmes.)(jc5) (Entered: 11/04/2021)

* Identifies a text-only order on appeal.

FORM 19. Certificate of Compliance with Type-Volume Limitations

Form 19
July 2020

UNITED STATES COURT OF APPEALS
FOR THE FEDERAL CIRCUIT

CERTIFICATE OF COMPLIANCE WITH TYPE-VOLUME LIMITATIONS

Case Number: 2023-1715

Short Case Caption: Jiaxing Super Lighting Electric Appliance, Co., Ltd. v. CH Lighting Technology Co., Ltd.

Instructions: When computing a word, line, or page count, you may exclude any items listed as exempted under Fed. R. App. P. 5(c), Fed. R. App. P. 21(d), Fed. R. App. P. 27(d)(2), Fed. R. App. P. 32(f), or Fed. Cir. R. 32(b)(2).

The foregoing filing complies with the relevant type-volume limitation of the Federal Rules of Appellate Procedure and Federal Circuit Rules because it meets one of the following:

- [x] the filing has been prepared using a proportionally-spaced typeface and includes 13,993 words.
- [ ] the filing has been prepared using a monospaced typeface and includes ________ lines of text.
- [ ] the filing contains ________ pages / ________ words / ________ lines of text, which does not exceed the maximum authorized by this court's order (ECF No. ________).

Date: 07/25/2023

Signature: /s/ Jeffrey A. Lamken

Name: Jeffrey A. Lamken